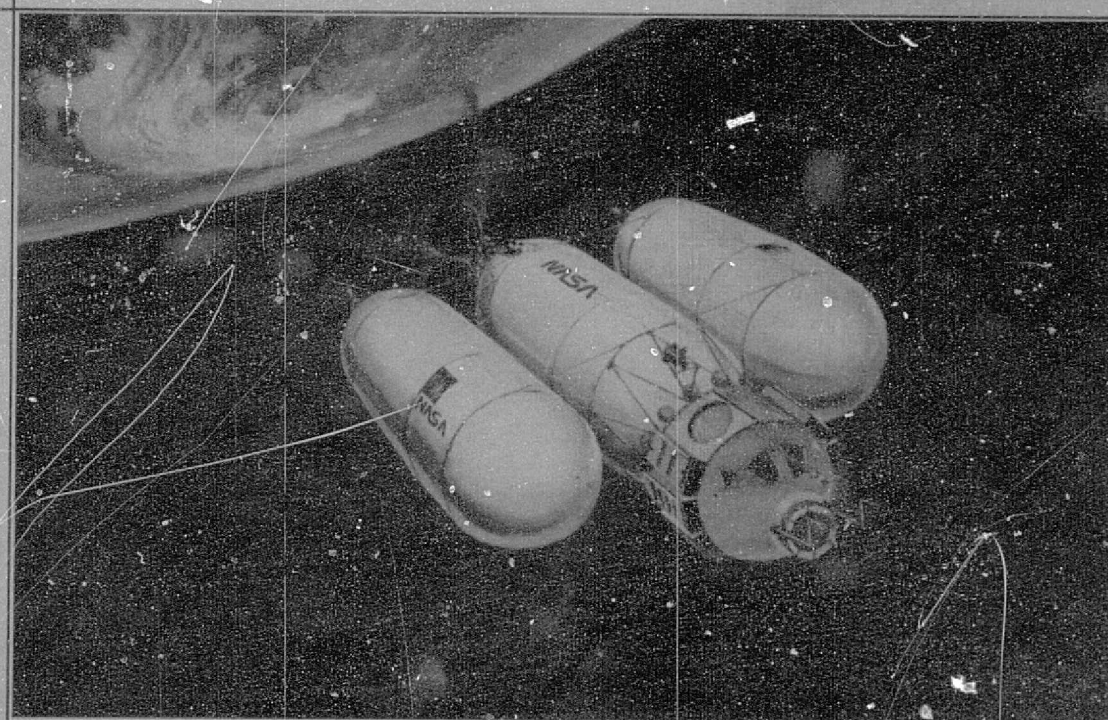
3rd quarterly review

MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS & SYSTEMS ANALYSIS STUDY EXTENSION



GRUMMAN AEROSPACE CORPORATION

MOTV

GRUMMAN

INTRODUCTION

OPERATIONAL REQMTS
ANAL. & DEFINITION

MOTV CONCEPTS SUMMARY
EVALUATION

CONCLUSIONS &
RECOMMENDATIONS

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MOTV

SCHEDULE & MILESTONES

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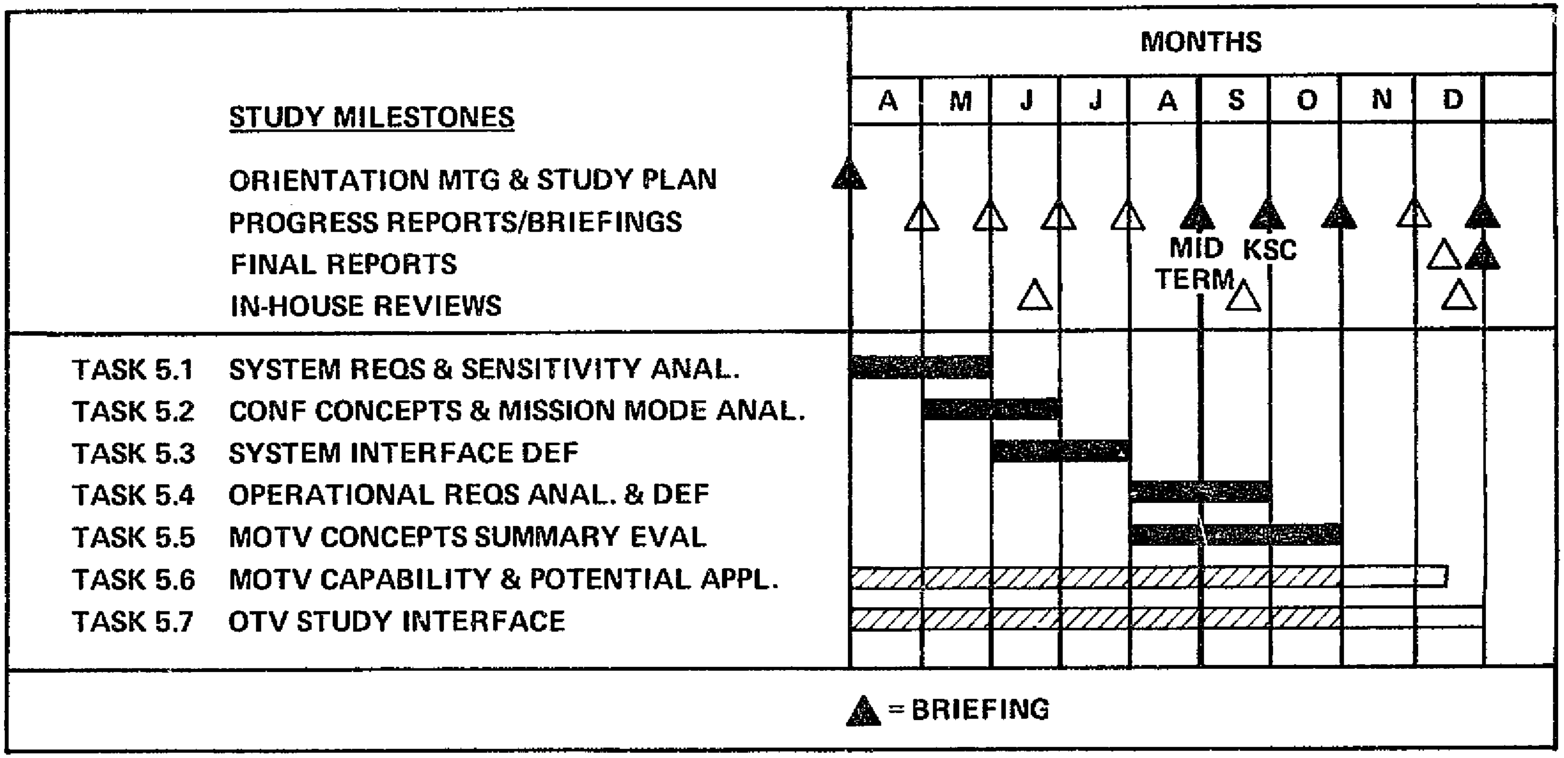

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MOTV

TASK 5.4

OPERATIONAL REQUIREMENTS ANALYSIS AND DEFINITION

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OBJECTIVE: DEFINE THE TURNAROUND REQUIREMENTS FOR THE MOTV BASELINE AND ALTERNATE CONCEPTS WITH/WITHOUT A SOC

- ANALYZE TURNAROUND REQUIREMENTS WITH/WITHOUT SOC FOR MOTV CHECKOUT, MAINTENANCE, REFURBISHMENT, RESUPPLY AND REFUELING
- DETERMINE THE MOST EFFECTIVE COMBINATION OF GROUND-BASED AND SPACE-BASED TURNAROUND ACTIVITIES
- ESTABLISH FAILURE MODE GROUND AND FLIGHT OPERATIONAL REQUIREMENTS
- IDENTIFY GROUND AND FLIGHT OPERATIONS REQUIREMENTS FOR ABORT
- IDENTIFY LOW COST APPROACHES TO SPACE AND GROUND OPERATIONS THROUGH MAINTENANCE AND MISSIONS SENSITIVITY STUDIES

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TASK 5.5

MOTV CONCEPTS SUMMARY EVALUATION

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OBJECTIVE: COMPARE, RATE AND RECOMMEND A PREFERRED MOTV CONFIGURATION & MISSION MODE

- DEVELOP CRITERIA FOR COMPARATIVE EVALUATION OF MOTV CONCEPTS, i.e., COST, PERFORMANCE, SAFETY, UTILITY, ETC.
- COMPARE CONCEPTS USING NASA-APPROVED CRITERIA AND WEIGHTING FACTORS
- RECOMMEND A PREFERRED CONFIGURATION AND MISSION MODE

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MOTV

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MOTV TURNAROUND ANALYSIS

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BACKGROUND DATA

SOC/GND TURNAROUND ANALYSIS

RECOMMENDED SOC/GND MIX & SUPPORT REQMTS

CONCLUSIONS

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GENERIC MISSION SUMMARY

The salient characteristic of each generic mission is shown in the accompanying illustration. Five generic categories are identified on the right hand side of the table; within each category is a wide sampling of missions. They range from short duration, small crew size, and low mission hardware weight to orbit, to long duration, large crew size, and heavy mission hardware weight to orbit. Mission orbits range from GEO to 12 hr/63° elliptic, to deep space (400,000 n mi circular).

Turnaround support requirements were developed for the S-1 mission since it included the requirements of the majority of the other missions.

MOTV

GENERIC MISSION SUMMARY

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GENERIC MISSION		SCENARIO CHARACTERISTICS				
CATEGORY	SYMBOL	ORBIT	MISSION HDWR, Kg	CREW	DURATION, DAYS	DESCRIPTION
INSPECTION SERVICE & REPAIR	IN1	GEO	510	2	4	SCIENTIFIC SATELLITE REVISIT
	[S1]	GEO	1684	3	19	MODULAR LEVEL SERVICE
	S2	GEO	2966	3	27	COMPONENT LEVEL SERVICE & UPDATE
	S3(a)	GEO	2600	2	21	SERV & UPDATE NUCL PWRD SATS
	S3(b)	GEO	2600	2	3	REPLACE NUCL REACTOR
	ER1	GEO	453	2	4	EMERGENCY REPAIR (GEO)
	[ER2]	12 HR/63	272	2	4	EMERGENCY REPAIR (HEO)
	R1	12 HR/63	4100	3	2	FAILED SATELLITE
OPERATION OF LARGE SPACE SYSTEM	OP1	GEO	440	2	16	TENDED STD
	P1	GEO	1683	2	4	3 MAN CREW ROTATION/RESUPPLY
	[P2]	GEO	4485	2	4	10 MAN CREW ROTATION/RESUPPLY
	P3	GEO	16,819	2	4	30 MAN CREW ROTATION/RESUPPLY
	[P4]	DEEP SPACE	3364	2	30	6 MAN CREW ROTATION/RESUPPLY
DEBRIS REMOVAL	[DR1]	GEO	550	2	9	REMOVE DEBRIS FROM 45° SECTOR OF GEO
CONSTRUCTION	C1	GEO	10,000	2	3	UNFOLD WIRE WHEEL ANTENNA
	C2	GEO	16,000	3	6	UNFOLD COMMUN PLATFORM
	[C3]	GEO	17,000	3	6	PREFAB COMMUN PLATFORM
	C4	GEO	15,000	3	7	AUTOFAB COMMUN PLATFORM
	C5	GEO	110,535	3	14/5/5/5	AUTOFAB SPDA
	[C6]	GEO	–	2	17	MODULAR ASSY SPDA
UNMANNED CARGO	UC	VARIOUS	15,000 55,000	NONE		SECONDARY ROLE

SYMBOLS

IN = INSPECTION
S = SERVICE
ER = EMERG REPAIR
R = RETRIEVAL
OP = OPER. LG SPACE SYSTEM
P = PASS. TRANSPORT
DR = DEBRIS REMOVAL
C = CONST
UC = UNMAN. CARGO

[ ] SELECTED FOR DETAILED STUDY

1776-191W

MOTV VEHICLE CONFIGURATION

The accompanying illustration is an artist's rendering of the MOTV configuration capable of accomplishing the S-1 mission. It includes three external tanks, a crew and a propulsion core module. LRU repla: ments for the satellite to be serviced at GEO are carried on the exterior of the crew module to facilitate accessibility. Grapplers and a berthing ring are part of the mission support hardware to facilitate replacement of defective GEO satellite hardware.

MOTV

MOTV TRANSFER TO GEO

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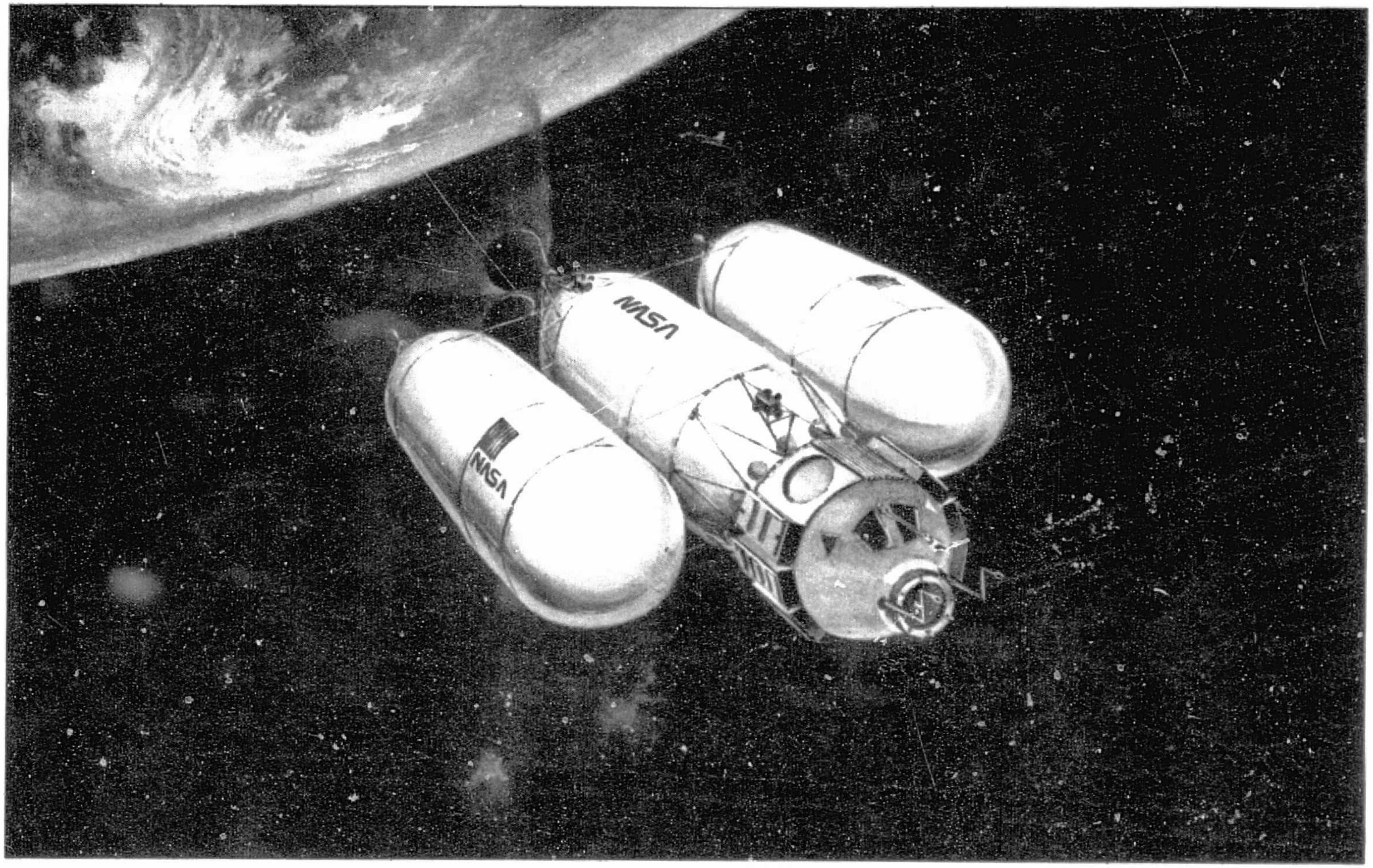

MOTV SUBSYSTEM ALLOCATION

This illustration shows the placement of the various subassemblies in the MOTV. In the Displays and Controls and the Rendezvous Radar Subsystems, all the subassemblies are located in the Crew Capsule. For the other subsystems, percentages indicate where the subassemblies are placed. The percentages are based on the number of components or subassemblies located in each module. The location criteria as shown was used in determining the placement of the subassemblies. This arrangement will provide autonomy to the OTV configuration as well as maximize accessibility of LRU components for SOC or GND servicing.

MOTV SUBSYSTEMS ALLOCATION

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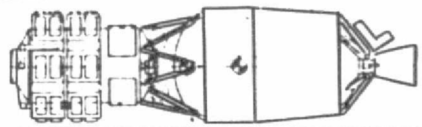

SUBSYSTEM	CREW CAPSULE	PROP. MODULE	DROP TANKS
DISPLAYS & CONTROLS	ALL		
DATA MANAGEMENT	TAPE RECORDER, (30%) SIGNAL CONDITIONERS BIO-MED + ECLSS SENSOR	60%	TEMP, PRESSURE (10%) SENSORS
ATTITUDE CONTROL &	MANUAL NAVIGATIONAL (30%) CONTROLS, KEYBOARD COMPUTER INPUT, DIGITAL INTERFACE UNIT	70%	
TRACKING, TELEMETRY & COMMAND	CREW MICS., EARPHONES, (15%) ENCRYPTORS, DECRYPTORS	85%	
RENDEZVOUS RADAR	ALL		
EPS	CONTROLS & CKT (20%) PROTECTION	80%	
ECLSS	LIFE SUPPORT & (95%) ENVIRONMENTAL CONTROL	5% EQUIPMENT CONDITIONING	
MAIN PROP	0	2 ENGINES 100% & PROP SYS	ADDITIONAL FUEL TANKS
RCS MODULES	0	RCS THRUST & FEED SYS 100%	

LOCATION CRITERIA
- MAINTAINABILITY
- RELIABILITY
- WEIGHT/CG
- UNNAMED FLIGHT
- ON-ORBIT REPAIR
- DETERMINED BY USE

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MOTV TURNAROUND SCENARIO

The turnaround scenario on the accompanying illustration illustrates the major activities of a typical S-1 mission and scopes the turnaround operation which include LEO rendezvous, assembly, and final mission preps as well as ground maintenance, refurbishment, and launch. The illustration also indicates that turnaround accounts for the major portion of the total mission and is, therefore, a prime cost driver. Thus, turnaround activities command much attention and analysis if program costs are to be minimized.

MOTV TURNAROUND SCENARIO

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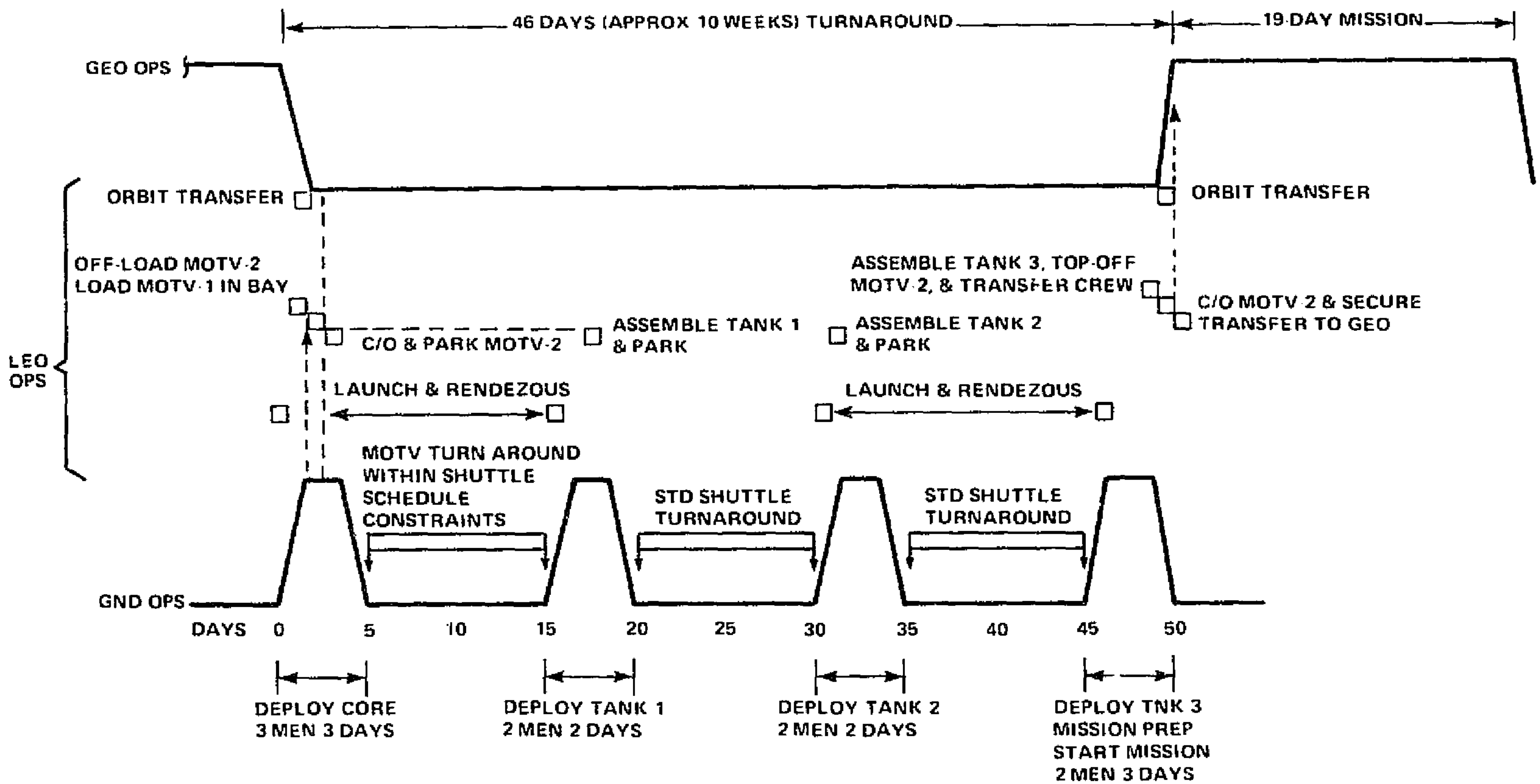

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OTV/MOTV GROUND TURNAROUND ACTIVITY

Our preliminary ground turnaround activity baseline is illustrated in the accompanying chart. After being removed from the Orbiter in the OPF, the returning Core/Manned Module (CMM) is put in a horizontal cannister. The cannister is routed directly to the OTV/MOTV Payload Processing Facility (PPF) for complete maintenance operations. At the PPF the crew module is demated and processed on a horizontal workstand. The propulsion core module is processed in a vertical work stand. For OTV flights the propulsion core module is taken to the VPF and integrated with other STS cargo in the vertical Cargo Integration Test Equipment (CITE). For MOTV flights the crew and core module are taken separately to the VPF and integrated in the vertical CITE. For either of these flights the propulsion core module is fueled on the pad in parallel with STS fueling operations.

Detail functional flows, timelines, and manpower estimates for this baseline were developed and analyzed relative to total time, manpower, GSE/facility requirements, and sensitivities.

MOTV

OTV/MOTV GROUND TURNAROUND ACTIVITY

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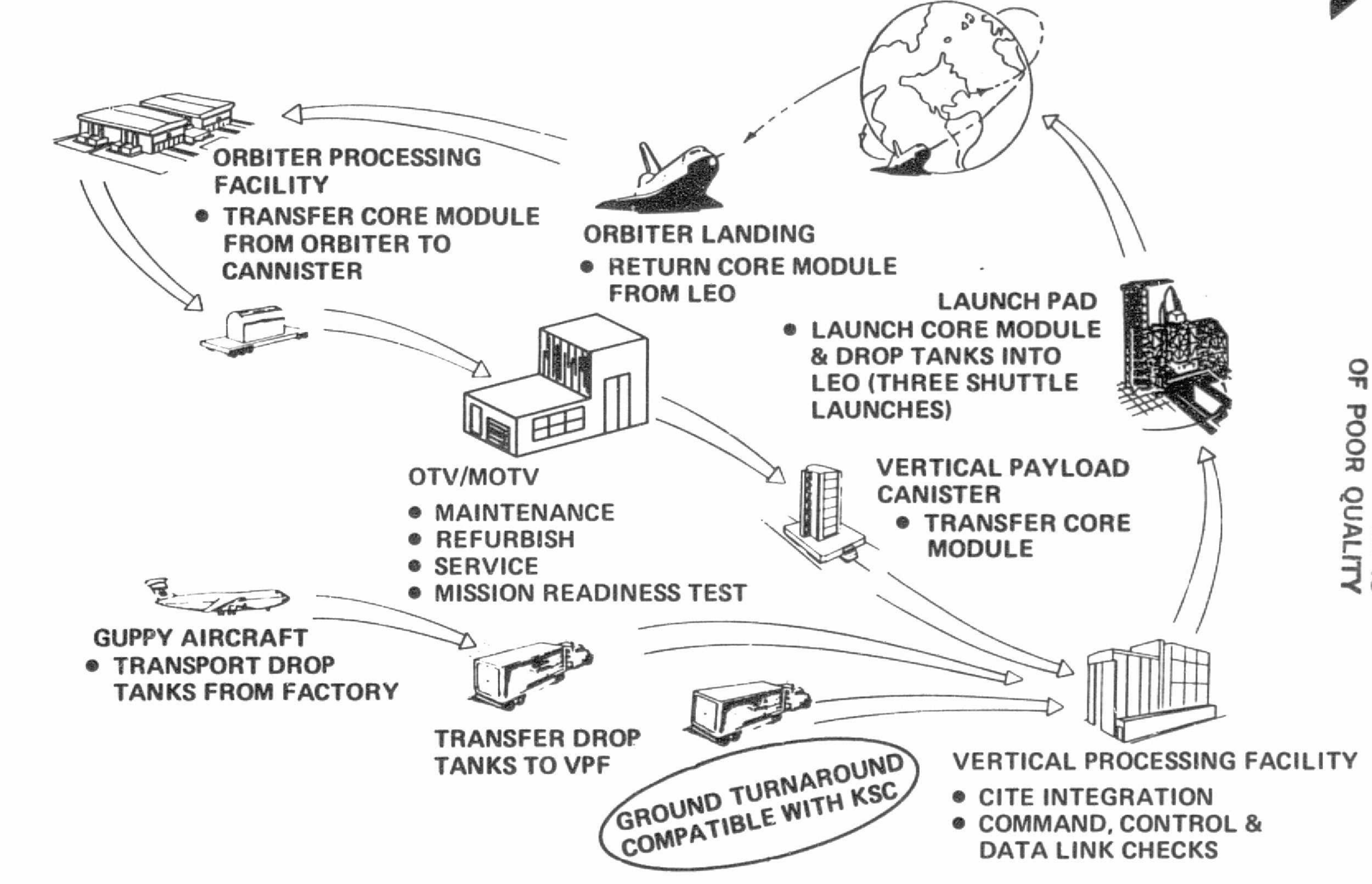

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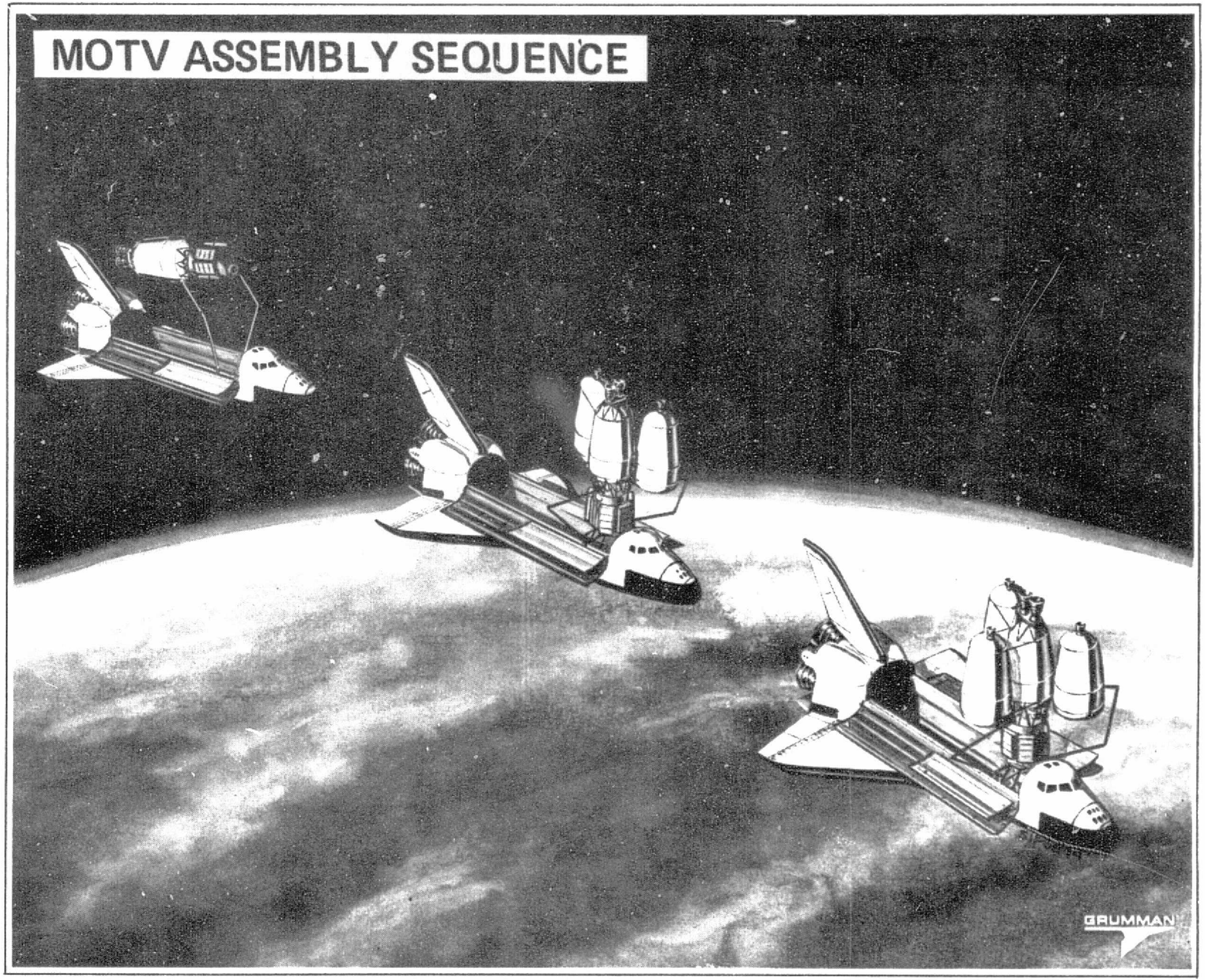
MOTV ASSEMBLY SEQUENCE

The accompanying illustration shows the assembly operations required at LEO for the ground turn-around of an S-1 MOTV flight.

The first sequence shows the crew/core module being deployed at LEO. The altitude stabilization system incorporated in the crew/core module will be used to stabilize the vehicle. The next sequence shows the second tank being installed. The same operations are required for the second as for the first tank, which is not illustrated. These operations include capture of the core/crew module, placing it and securing it to the berthing ring, installing the drop tank carried in the P/L bay of the Orbiter, checking out the interfaces (mechanical and functional) and deploying the configuration. This sequence is repeated for the last drop tank installation. The final tank assembly includes a crew transfer after the interfaces have been checked. Once the crew is aboard they will activate the MOTV systems and make final mission checks prior to transferring to GEO.


MOTV ASSEMBLY SEQUENCE
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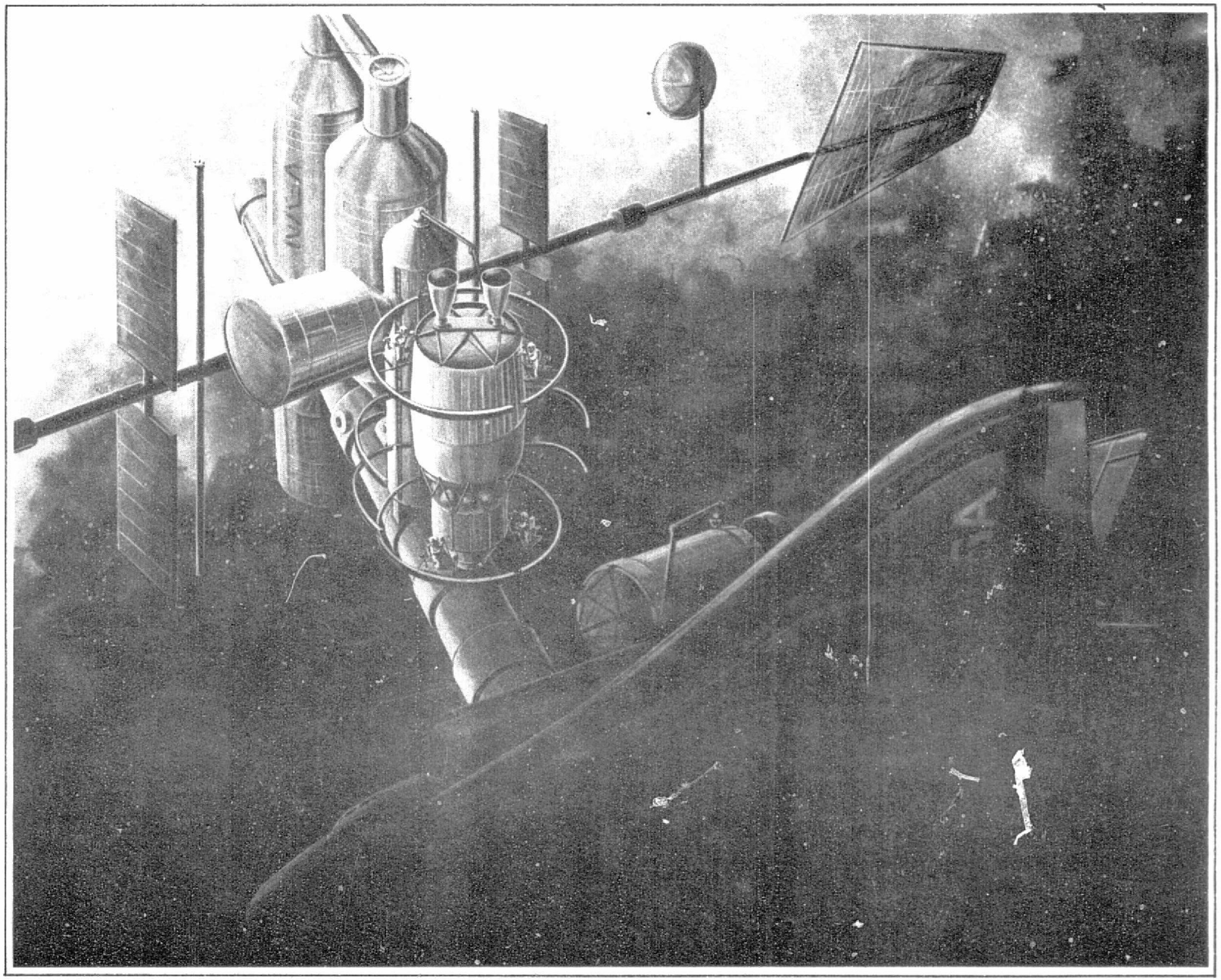
SOC MOTV TURNAROUND FACILITY

The accompanying illustration is an artist's rendering of what a SOC MOTV turnaround facility might look like. It would include work platforms, berthing capability, logistics modules and drop tank plus crew/core modules work stands. Specific functional capabilities will be described by subsequent illustrations.

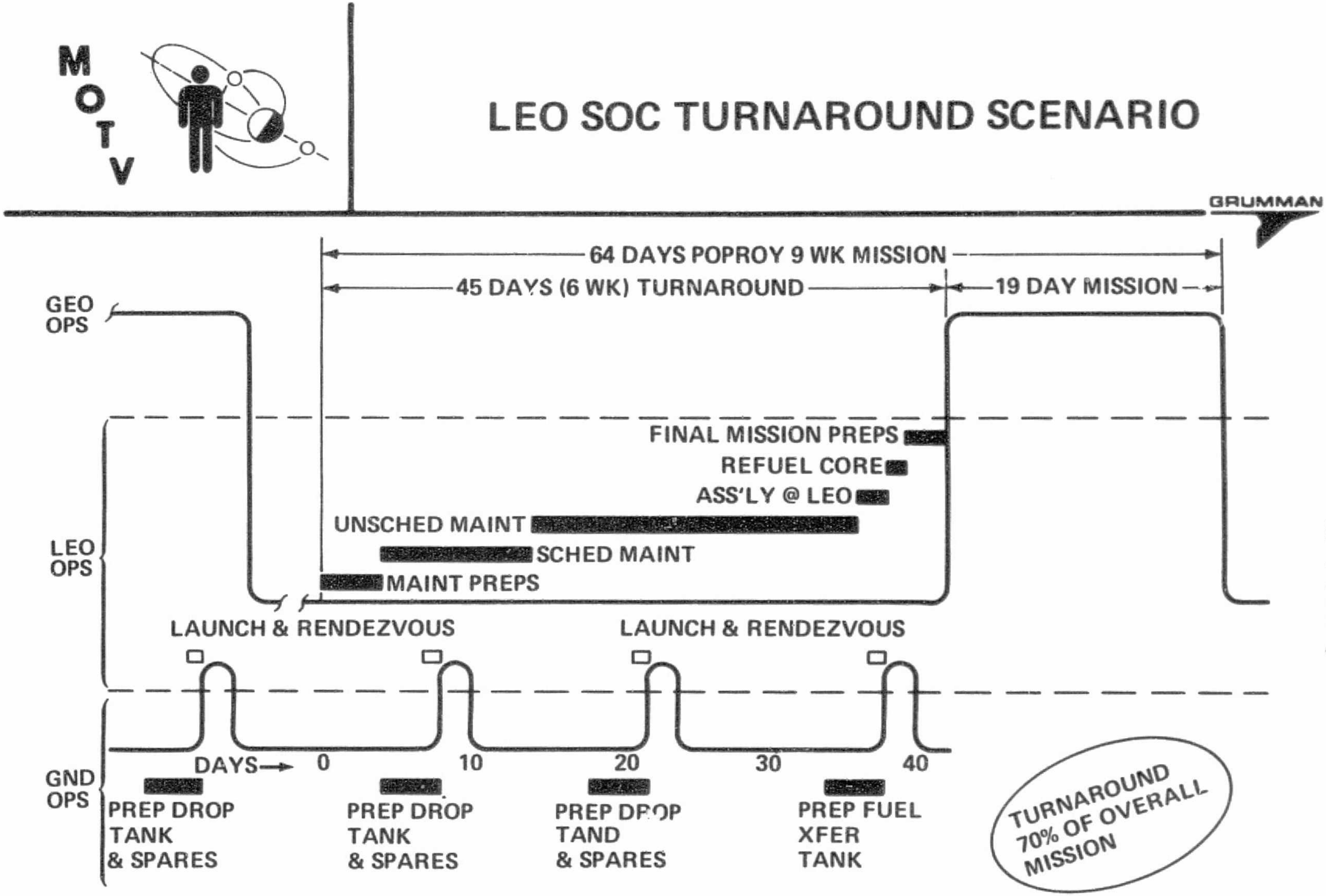


LEO SOC TURNAROUND SCENARIO

The turnaround scenario on the accompanying illustration shows the major activities of a typical S-1 mission and scopes the turnaround operation which includes LEO maintenance, refurbishment, assembly, refuel and mission preparation.

Although the STS supporting flights are shown evenly spaced, they can occur at any time during turnaround operations. SOC turnaround, in fact, decouples the STS support from the turnaround operations because the drop tanks are not required until the maintenance operation are complete; they could be brought up at any time prior to this within the venting requirements which are not critical in space. This decoupling is an important advantage of SOC turnaround because of the projected traffic model and demands for STC flights.

LEO SOC TURNAROUND SCENARIO



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SOC TURNAROUND ACTIVITY

The accompanying illustration shows the major activities required at LEO for SOC turnaround. Following rendezvous, the returning OTV or MOTV configuration is captured, berthed, and prepared for the required maintenance tasks. Maintenance at SOC would consist of safety and damage inspection, replacement of defective hardware (LRUs) and reconfiguring for flight. Mission preparation would consist of servicing the required systems, refueling and final systems checks prior to GEO transfer.

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SOC TURNAROUND ACTIVITY

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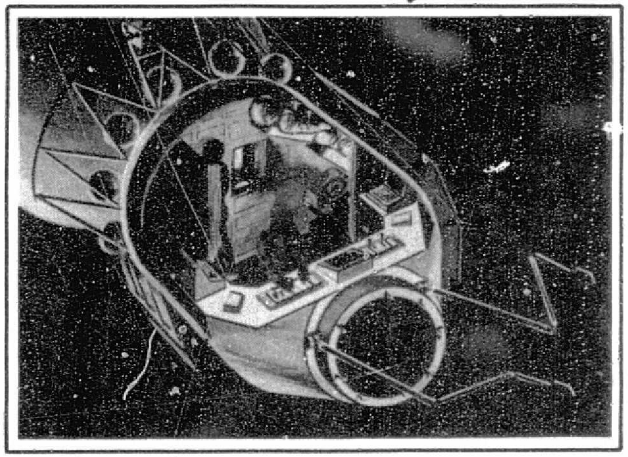
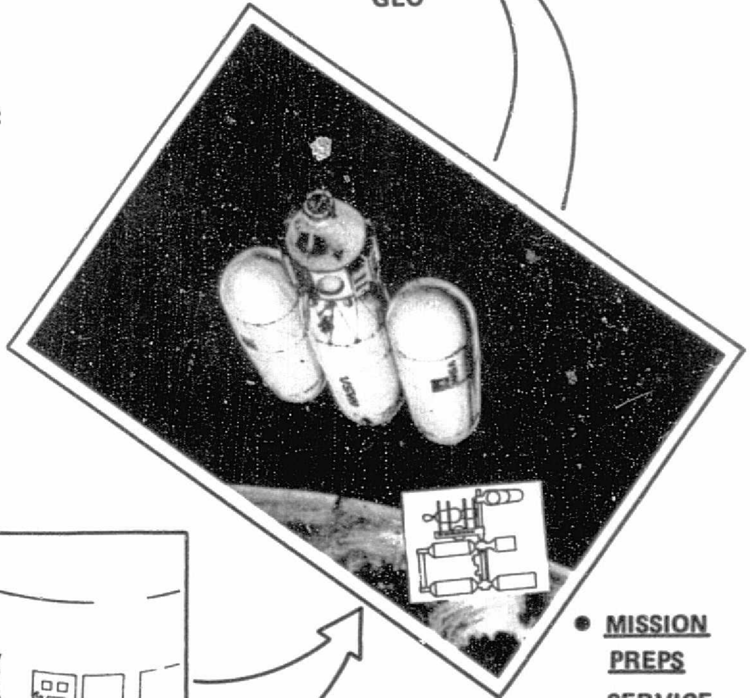


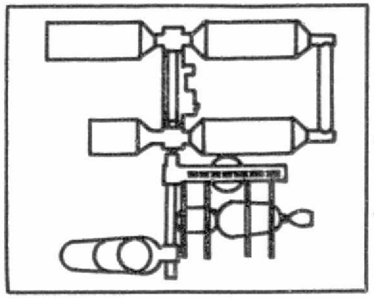
- **RENDEZVOUS**
  - LOCATE SOC
  - TRACK SOC
  - STEER TO SOC

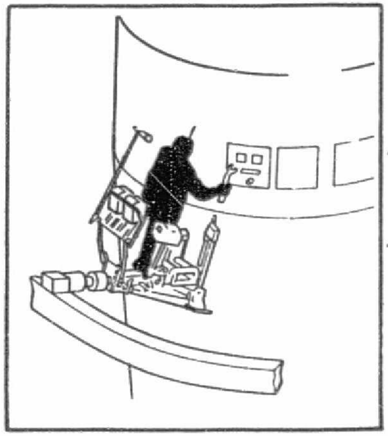
GEO



- **MISSION PREPS**
  - SERVICE
  - REFUEL
  - OVERALL SYSTEMS C/O

- **MAINTENANCE PREPS**
  - BERTH WITH SOC
  - INSTALL WORK PLATFORMS
  - HOOK UP GSE
  - TRANSFER CREWS





- **MAINTENANCE**
  - INSPECT
  - REPLACE HDW
  - RECONFIGURE
  - VERIFY

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OTV/MOTV TURNAROUND APPROACH

The illustration on the accompanying page summarizes the approach used to develop our OTV/MOTV turnaround activity, i.e., maintenance requirements, functional flows, timelines, and manpower estimates. It identifies the philosophy, methods and techniques required to implement the approach which calls for emphasis on the use of flight data and inspections to make the initial assessment on the condition of the subsystems and major components. Maintenance would be accomplished on the basis of the condition of the equipment with a few exceptions like batteries, fuel cells and engines which are limited life items. This approach was developed as a result of studying the airlines' jumbo jet experience and our own military aircraft experience.

MOTV TURNAROUND APPROACH

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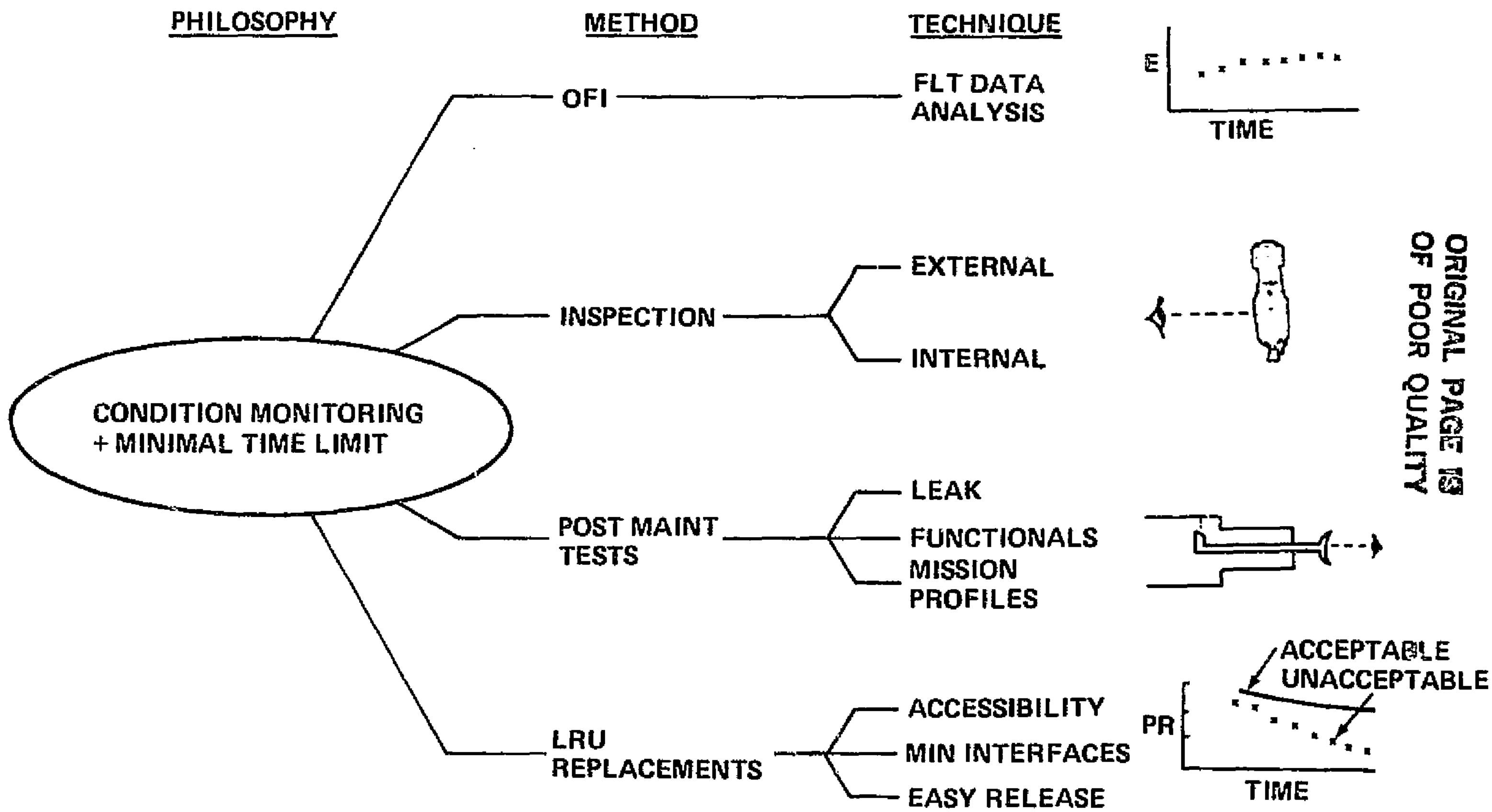

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MAINTENANCE SUBSYSTEM REQUIREMENTS

The accompanying illustration shows the first step in determining maintenance requirements. Each subsystem was analyzed including synthesis of functional schematics, if none were available, and definition of what, when (how often), how, and a time estimate for the task. The illustration also shows that physical inspections for damage (meteroid or inadvertent) are the only checks made on a regular, post flight, basis. Performance monitoring is accomplished by analyzing flight data with ground tests conducted only if flight data, violation of the subsystems' integrity, or overhaul require specific tests.

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MAINTENANCE SUBSYSTEM REQUIREMENTS

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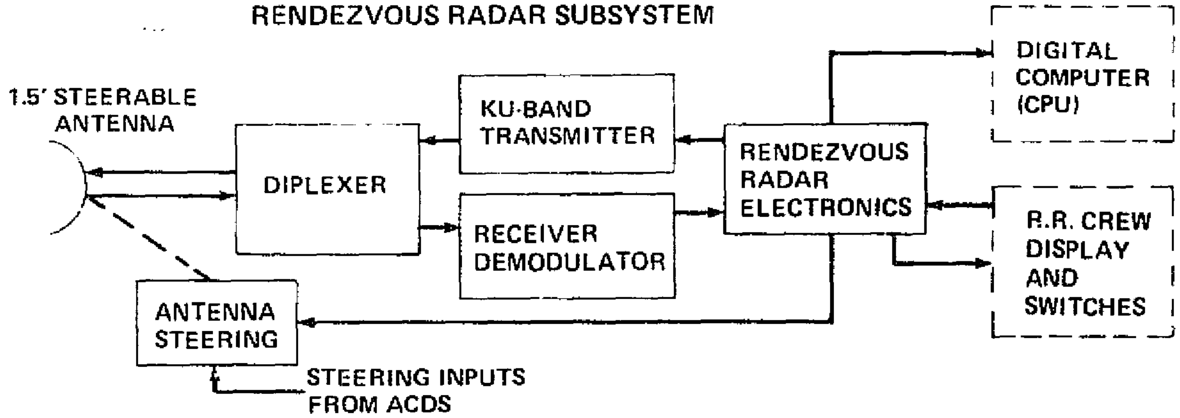
RENDEZVOUS RADAR SUBSYSTEM



PER SUBSYSTEM
WHAT, HOW, &
HOW OFTEN

REQUIREMENT	WHEN	HOW	TASK TIME
1. ANTENNA SERVO			
• INSPECT	POST FLIGHT	VISUAL	30 MIN
• SLEWING	FLIGHT CRAB/OVERHAUL	OF I	
2. TRANSMITTER RECEIVER			
• INSPECT	POST FLT	VISUAL	30 MIN
• VSWR, PWR CHECK	FLT CRAB/OVERHAUL	OF I	
• RECEIVER SENSITIVITY, STABILITY	PERIODIC FLT CRAB OVERHAUL	OF I	15 MIN
3. R.R. ELECTRONICS			
• RANGING	PERIODIC FLT CRAB OVERHAUL	OF I	15 MIN
• OVERALL PERFORMANCE	FLT CRAB OVERHAUL	OF I	

CORE MODULE REFUELING IN LEO TIMELINE

The accompanying illustration timelines the core refueling steps. The time is shown in equivalent ground manhours for the SOC configuration.

Each tank is chilled down and conditioned prior to final fill; the LH_2 & LO_2 operations are accomplished serially instead of in parallel because of safety considerations.

MOTV

CORE MODULE - REFUELING IN LEO GROUND EQUIV

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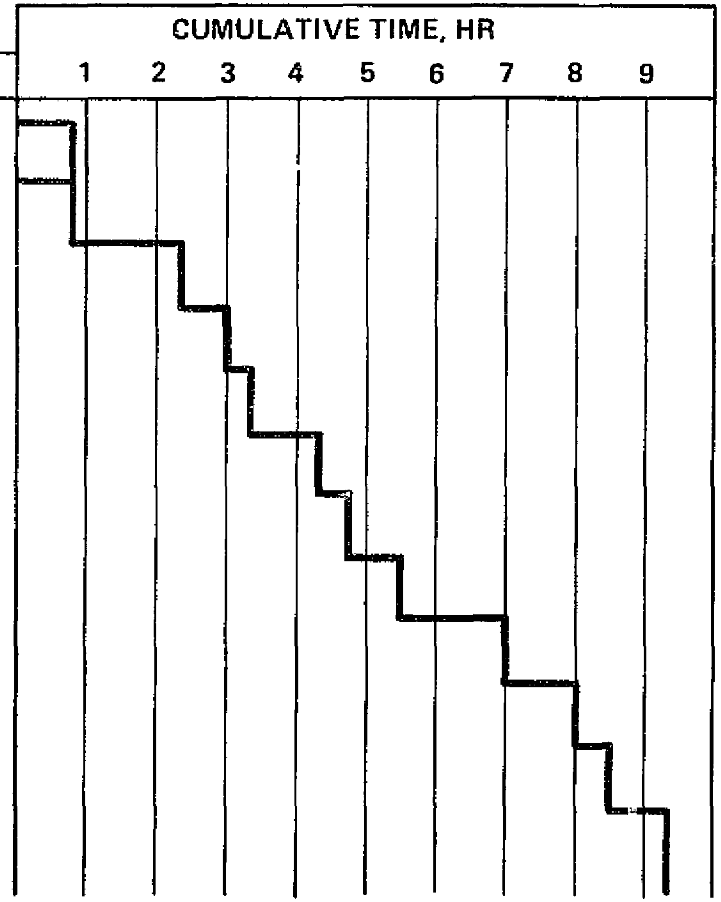
TASK	TIME, HR
1 PREPARE & C/O OCP	0.8
2 VENT LH_2 TANK & ATTACH FILL LINE*	0.8
3 FILL WITH LH_2 & CHILLDOWN TANK	1.5
4 VENT & REFILL LH_2 TANK	0.7
5 THERMAL HOLD	0.3
6 VENT & FINAL FILL LH_2 TANK	1.0
7 VENT, PURGE & DISCONNECT FILL LINE	0.4
8 VENT LO_2 TANK & ATTACH FILL LINE	0.5
9 FILL WITH LO_2 & CHILLDOWN TANK	1.5
10 VENT TANK & FINAL FILL WITH LO_2	1.0
11 VENT, DISCONNECT & STORE LO_2 LINE	0.3
12 DEACTIVATE & STORE OCP	0.5
TOTAL TIME	8.5



* PARALLEL TASKS

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MOTV PROPULSION CORE & MANNED MODULE (CMM) FUNCTIONAL TURNAROUND REQUIREMENTS

The accompanying illustration depicts the next step taken to define the turnaround requirements. Each activity, starting from removal of the OTV/MOTV from the orbiter, is broken down and analyzed for handling, transportation, preparation and subsystem test requirements. For each requirement the man hours required are calculated based on the type of activity and number of people required, a judgment is made as to the need for software and support equipment. This effort was continued for all of the crew module, core propulsion module activities in the OTV/MOTV Processing Facility, the Vertical Processing Facility (VPF), Cargo Integration Test Equipment (CITE) and the pad operations. It provided the data baseline for the trades and support requirements developed.

MOTV PROPULSION CORE & MANNED MODULE (CMM) FUNCTIONAL TURNAROUND REQMTS

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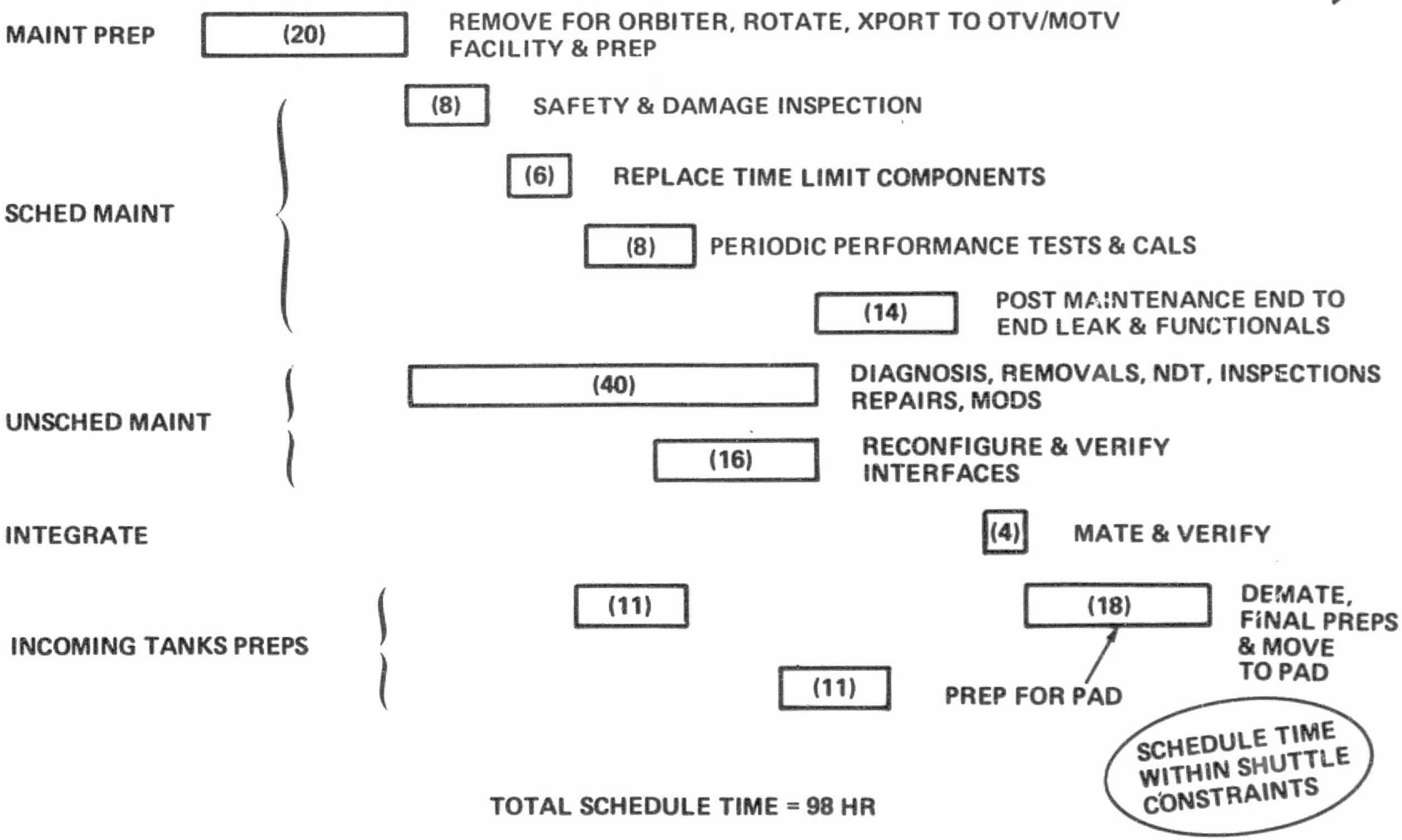
TASK NO.	LOCATION	INTEG LEVEL	FUNCTIONAL REQMT	MANHOURS	SOFTWARE	EQUIPMENT	REMARKS
1.0	LANDING AREA	I	NONE	–	–	–	FINAL MOTV C/O PRIOR TO LNDG-RE-MOVE FLT
2.0	ORBITER		INSTALL P/L ACCESS PLATFORMS	8	NONE	WK PLATFORMS	ORBITER EQUIP. & TAPES
2.1	PROCESSING FACILITY		CORE/MAN MODULE (CMM) PRELIM. INSPECTION & PHOTOS	4			
2.2			ATTACH HANDLING SLING & STRONG BACK	3		SLINGS & STRONGBACK	STRONG BACK ST[illegible] RBITER EQU[illegible]PMENT
2.3	OPF	II	INSTALL CMM IN HORIZONTAL CANNISTER	6			
2.4			INSTALL CANNISTER ON XPORTER	2			
2.5			EXPORT TO OTV/MOTV P/L PROCESSING FACILITY	8			
3.0	OTV/MOTV PROCESSING FACILITY		CLEAN XPORTER & CANNISTER IN FACILITY AIR LOCK	8		NONE	FACILITY EQUIPMENT
3.1			PLACE CANNISTER NEXT TO	2			CRANE USED FOR CMM INSTALLATION
3.2			REMOVE MODULES FR CANNISTER	4			
			INSTALL IN WORK STAND	4			
3.3			POSITION WORK PLATFORMS			WK PLATFORMS	
3.4			POSITION & MATE GSE	10		FLUID & ELECT.	
3.5			ESTABLISH CABIN CONDITIONING	2		GSE PLUS	
3.6			REMOVE ACCESS DOORS	12		LPS-HIM	

• CMM READY FOR MAINTENANCE & REFURBISHMENT

GROUND BASELINE TURNAROUND SCHEDULE

The updated ground baseline turnaround schedule is shown on the accompanying illustration, representing the MOTV alone (Level II) tasks required for turnaround. The total of 98 hr is within the Orbiter projected 160-hr turnaround requirement and Level I integration constraints. The illustration shows that unscheduled maintenance is the prime schedule driver, accounting for approximately 50% of the serial scheduled time.

UPDATED GROUND BASELINE TURNAROUND SCHEDULE



MANPOWER SENSITIVITY TO TURNAROUND LOCATION

This illustration shows the difference in turnaround manpower requirements as a function of location (i.e., ground vs LEO SOC). For each of the common activities (i.e., maintenance prep, scheduled and unscheduled maintenance), there is a significant increase for SOC Activities. A couple of activities (integration of the MOTV and launch preps) are not required for SOC turnaround. Overall SOC turnaround requires about twice the number of manhours. The reason for the increase in manhours is essentially a function of the efficiency of man in SOC during EVA and IVA tasks.

MANPOWER SENSITIVITY TO TURNAROUND LOCATION

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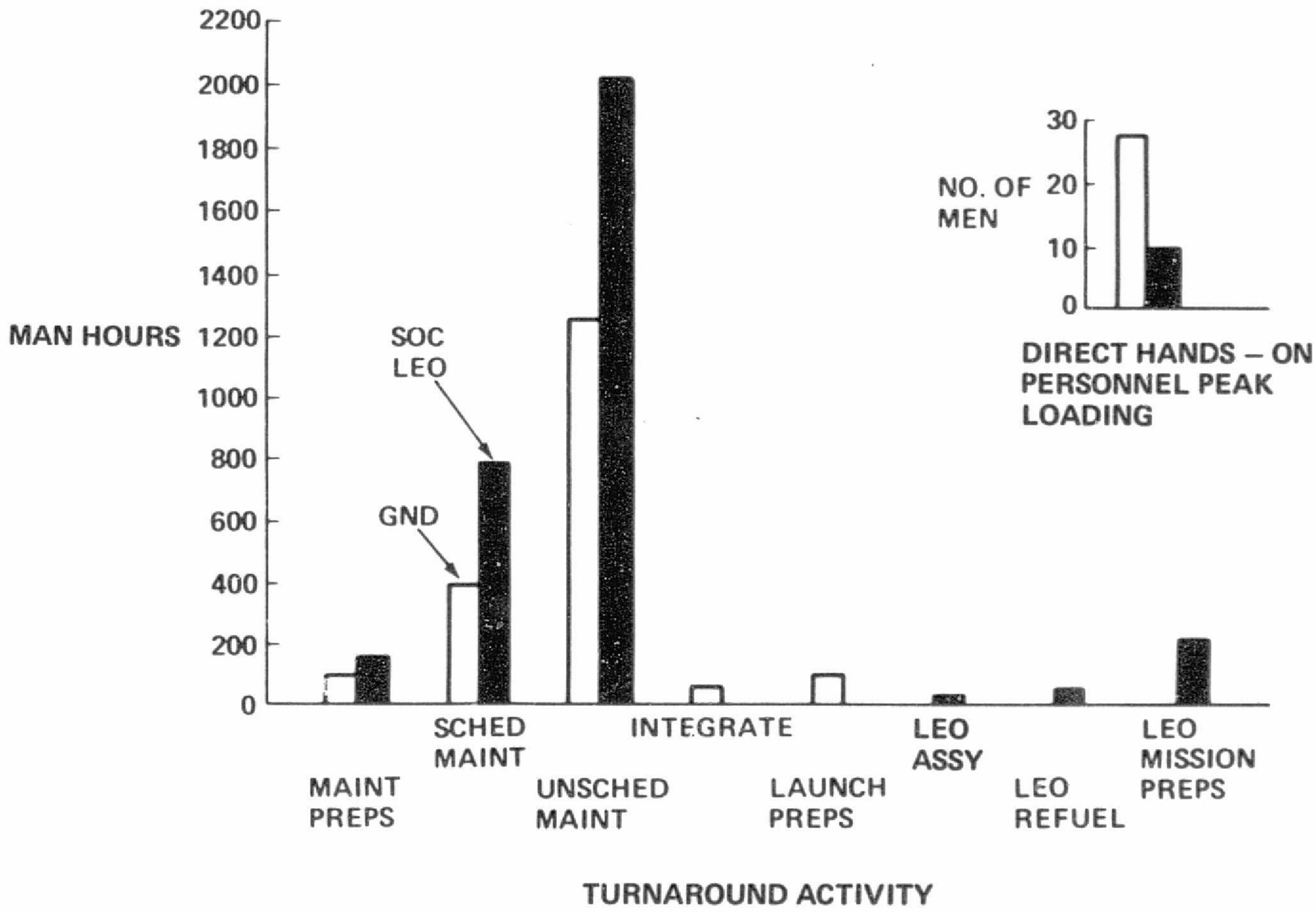

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TURNAROUND OPTIONS RELATIVE RATING SUMMARY

This illustration summarizes the results of the comparative analysis for ground-based, LEO SOC and LEO STS turnaround options. It shows that ground-based has the advantage in manhours, turnaround activity serial time and impact on support equipment. SOC has the advantage in overall turnaround schedule, the number of STS flights and the program cost/flight. The cost/flight is the most significant factor considered. The STS- tended does not offer any advantages. Another important advantage of SOC-based turnaround is that it decouples the STS support flights from the OTV/MOTV turnaround cycle which, in turn, allows the more efficient manifesting of the STS flights.

MOTV

TURNAROUND OPTIONS RELATIVE RATING SUMMARY

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	MAN HRs	TURNAROUND TASK SERIAL TIME DAYS	TURNAROUND OVERALL SCHEDULE DAYS	STS FLIGHTS & LOADING	COST/FLT XPORTATION M $	SUPPORT EQUIP M $	INITIAL INVEST & PAYBACK
GROUND BASED KSC	2100	14	51	3 FLTS @ 29,000 kg PLUS 2 PARTIAL FLTS	108	3.5	3.5
LEO SOC	4000	42	42	*3 FLTS @ 29,000 kg PLUS 1 FLT @ 15,000 kg	*97	13	*330 M 15 YR PAYBACK
LEO STS TENDED	5700	60	102	4 FLTS @ 29,000 kg	131	13	

*BASED ON SOC @ 200 N MI

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INITIAL STUDY TURNAROUND FINDINGS

The accompanying illustration summarizes the results of our initial ground and SOC turnaround analysis. It is self explanatory and identifies the viability of SOC turnaround providing the right mix of SOC/GND activities are established.

STUDY FINDINGS TURNAROUND

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• TURNAROUND APPROACH	FEATURING USE OF – FLIGHT DATA – TEST AUTOMATION – MAINTAINABILITY	REDUCES MANPOWER & GSE REQMTS	
• GROUND TURNAROUND	– FEATURES LOW STARTUP COSTS – FLEXIBILITY TO DEAL WITH CONTINGENCIES		
• SOC TURNAROUND	– VIABLE ALTERNATE WITH $12M SAVINGS PER MISSION – REQUIRES INITIAL INVESTMENT OF APPROX $300M		
• RECOMMENDATION	– IF FAVORABLE SOC ALTITUDE CAN BE ESTABLISHED AND/OR – INITIAL INVESTMENT REDUCED OR SHARED	– START WITH GROUND – ORDERLY TRANSITION TO SOC – USE STS TENDED TO DEVELOP HARDWARE & PROCEDURES	
	– DETERMINE MOST EFFECTIVE GND/SOC TURNAROUND MIX		

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MOTV

MOTV TURNAROUND ANALYSIS

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BACKGROUND
DATA

**SOC/GND
TURNAROUND ANALYSIS**

RECOMMENDED SOC/GND
MIX & SUPPORT REQMTS

CONCLUSIONS

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SOC/GND TURNAROUND OPTIMIZATION APPROACH

The accompanying illustration lists our approach toward developing the optimum SOC/GND turnaround mix. The approach indicated was straightforward and included defining the baseline turnaround cost drivers, defining the options available, establishing groundrules, performing the trades and developing the support requirements for each. The trade studies were then analyzed and the optimum GND/SOC turnaround mix selected. Support requirements for this mix were then summarized.

SOC/GND TURNAROUND OPTIMIZATION APPROACH

- DEFINE TURNAROUND COST DRIVERS
- DEFINE OPTIONS AVAILABLE
- ESTABLISH TRADE GROUND RULES
- DEVELOP TURNAROUND & SUPPORT REQMTS
- PERFORM TRADES
- SELECT SOC/GND TURNAROUND MIX
- SUMMARIZE RESULTS

MOTV TURNAROUND COST DRIVERS

The accompanying illustration lists the OTV/MOTV cost drivers which surfaced from a review of the baseline data. STS transportation costs relative to the number of flights and loading of each flight is the most critical single driver. For example, reduction of 25% of the P/L delivered to LEO will reduce turnaround costs by $7M. The next major cost driver is maintenance, more specifically, the number, type and frequency of maintenance tasks. Maintenance tasks at LEO are more critical because of the efficiency of man in performing EVA and IVA tasks. The number of people required is also directly affected by the amount of maintenance tasks and cost/man is greater on SOC that on the ground because of the added costs of maintaning a man on SOC.

MOTV TURNAROUND COST DRIVERS

- STS TRANSPORTATION COSTS
  - NUMBER
  - MANIFEST OR LOADING
- MAINTENANCE (PREPS, SCHEDULED & UNSCHEDULED)
  - NUMBER, TYPE & FREQUENCY OF TASKS
  - EVA/IVA
- NO. OF PEOPLE REQD
  - @ SOC/GND

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SOC/MOTV ANALYSIS GROUNDRULES

The accompanying illustration lists the groundrules developed for the turnaround analysis. These groundrules were established to provide consistency in evaluating the various options. The costing groundrules were obtained from JSC. The EVA/IVA conversion factors used were derived by researching Space Lab and other data, plus discussion with the JSC crew training personnel. The 8 missions per engine were derived based on mission engine firing requirements and the engine manufacturer's projected engine life - 5 hours between overhaul.

SOC/MOTV ANALYSIS GROUND RULES

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- MAN WORKING ON THE GROUND IS THE BASE LINE – HIS RATE IS $30/WK HR
- FOR SOC ON-ORBIT – IVA OPERATIONS MAN HOURS ARE 1.1 X THE BASE LINE & COST IS $900/WK HR
- FOR ROUTINE EVA OPERATIONS MAN HOURS ARE 3 X THE BASE LINE & COST IS $2400/WK HR
- FOR EVA NON-ROUTINE OPERATIONS MAN HOURS ARE 5 X THE BASE LINE & COST IS 16,000/WK HR PLUS A FIXED COST OF $96,000
- OTV/MOTV IOC IS 1992; OTV/MOTV FLT = 3/1; OTV TRAFFIC WILL BUILD UP FROM 3 - 5 FLT IN 5 YR
- SHUTTLE FLT IN '79 $ = 23.8M; SHUTTLE ON-ORBIT COSTS IS 500 K/DAY
- SOC CREW SIZE IS 8 MEN WITH 2 MEN REQD FOR HOUSEKEEPING & 6 MEN AVAILABLE FOR OTHER ACTIVITIES
- SOC AND MOTV CREW/PROPULSION MODULE DESIGN WILL FACILITATE SOC OPERATION
- ENGINE GOOD FOR 8 MISSIONS

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MOTV TURNAROUND OPTIONS

The accompanying illustration breaks down the turnaround option into three major categories: the vehicle configuration, the amount of maintenance performed, the use of a pressurized hangar at SOC. These major options break down into the subsets shown so that in total there are approximately 16 different options. Data was developed for each of these options and will be discussed in subsequent illustrations.

MOTV

MOTV TURNAROUND MAINTENANCE OPTIONS

GRUMMAN

OPTION	LOCATION OF ACTIVITY	
	GND	SOC
1 VEHICLE CONFIGURATION		
– COMPLETE MOTV	X	X
– PROPULSION CORE MODULE	X	X
– CREW MODULE	X	X
2 AMOUNT OF MAINTENANCE		
– BARE MINIMUM – GAS & GO – (PRE FLT)		X
– MINIMUM SCHED/UNSCHED (PERIODIC)		X
– COMPLETE MAINT & OVERHAUL	X	
3 MAINT WITH/WITHOUT PRESSURIZED HANGAR		X
4 COMBINATION OF ABOVE	–	–

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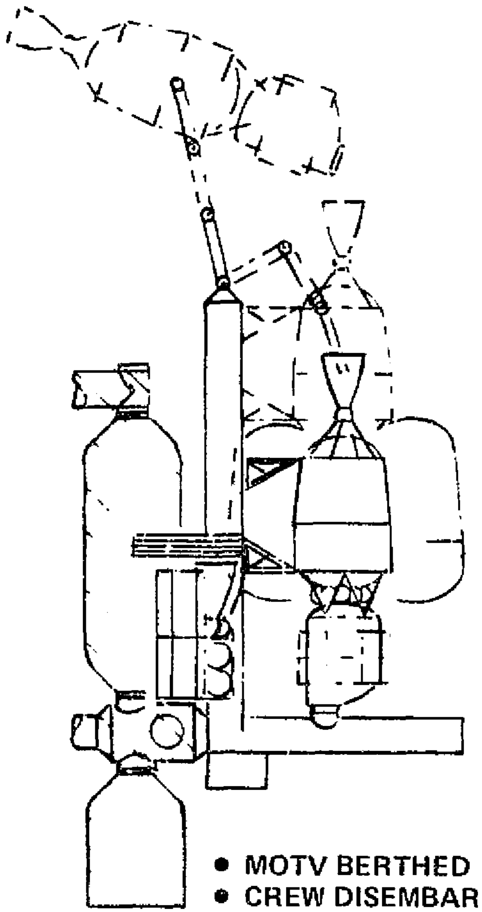
MOTV SERVICE SCENARIO AT SOC - EVA SERVICING (Sht 1)

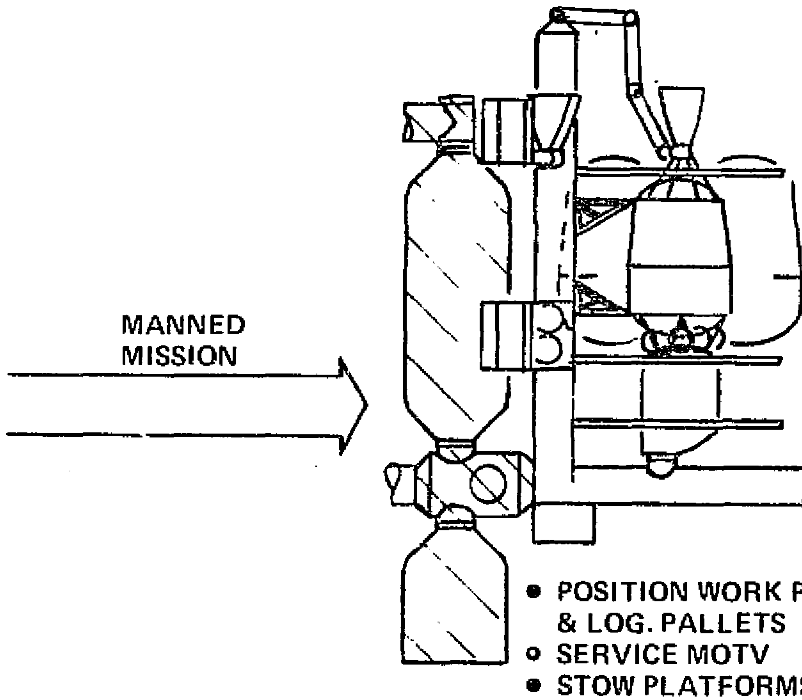
This illustration proposes a scenario for servicing an MOTV at SOC, using EVA. The MOTV returns from a manned flight, it is captured by a manipulator and berthed to a pressurized part of SOC for the crew to disembark. Assuming that the next mission is also manned, work platforms are positioned around the vehicle at suitable 'heights' for the EVA service crew to perform their tasks. Logistics pallets are positioned for the servicing crew to reach from their platforms. The MOTV is now serviced.

After servicing, platforms and pallets are moved out of the way, drop tanks are installed, propellant is transferred to the core. The mission crew then boards the MOTV, checks out the systems, then separates the vehicle from SOC using the berthing manipulator.

MOTV SERVICE SCENARIO AT SOC – EVA SERVICING (SHT 1)



- MOTV BERTHED
- CREW DISEMBARK



- POSITION WORK PLATFORMS & LOG. PALLETS
- SERVICE MOTV
- STOW PLATFORMS & PALLETS
- INSTALL DROP TANKS & LOAD CORE
- BOARD MOTV CREW
- C/O & SEPARATE

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MOTV SERVICE SCENARIO AT SOC - EVA SERVICING (Sht 2)

Considering EVA preparation of an OTV for an unmanned mission, this scenario starts with the return of an MOTV from a manned mission, as described on the preceding illustration. Having disembarked the crew, work platforms are positioned, propulsion core/crew capsule interfaces released, and then the core is separated from the crew capsule. Other work platforms and the logistics pallets are now positioned as required. The propulsion core is serviced and, if convenient, the crew capsule also.

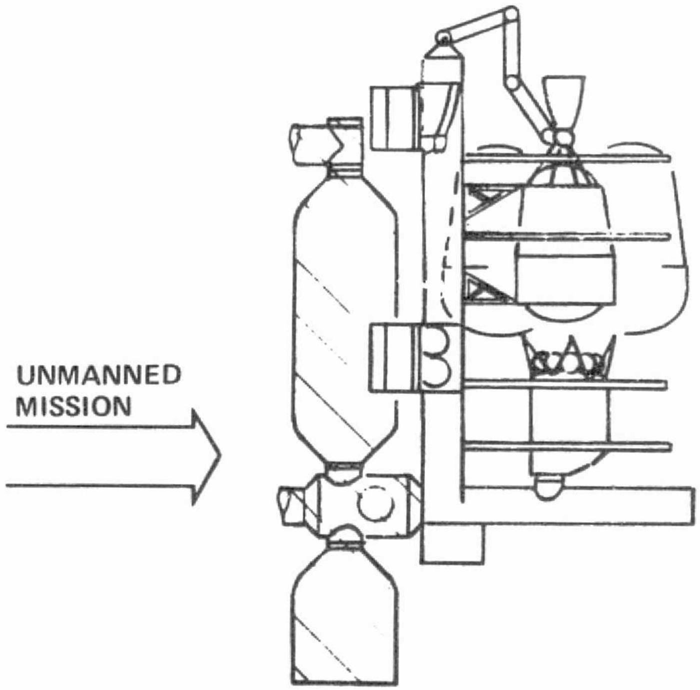
After servicing, platforms and pallets are moved out of the way, drop tanks are installed, propellant is transferred to the core. If necessary, the propulsion assembly is moved again to allow installation of the payload to the forward end. To make the necessary interfaces, a work platform is positioned to support the EVA crew.

The vehicle systems are checked out, then separated using the berthing manipulator to ensure no fouling of the SOC. The crew capsule may now be serviced, if it was not done so in parallel with the propulsion core.

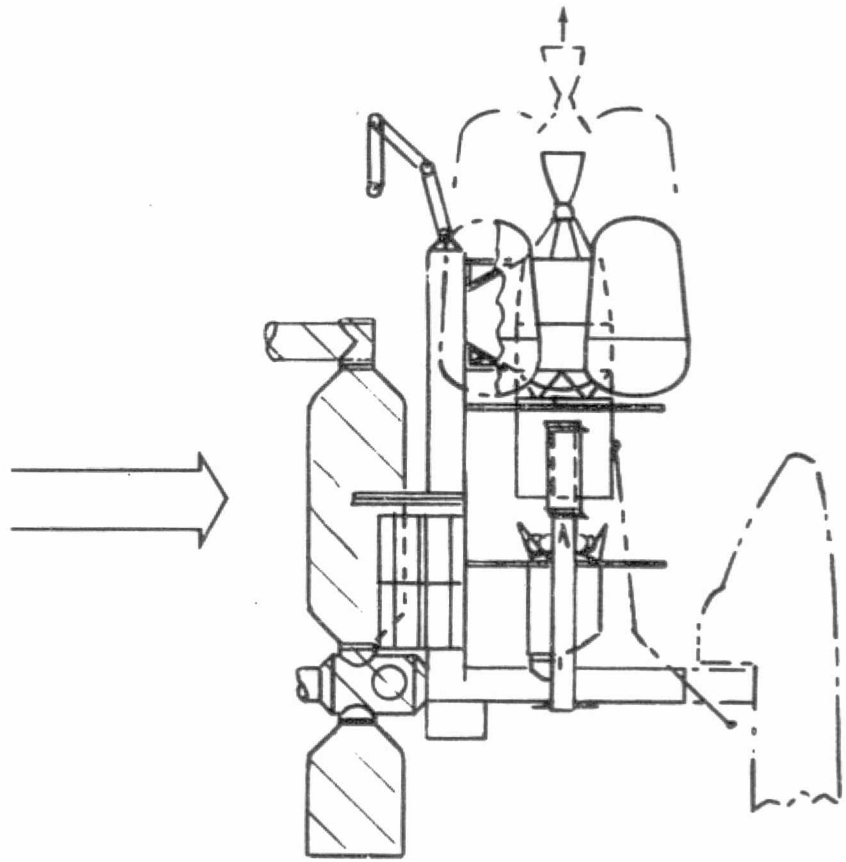
MOTV

MOTV SERVICE SCENARIO AT SOC – EVA SERVICING (SHT 2)

GRUMMAN



- SEPARATE PROP'N FROM CAPSULE
- POSITION WORK PLATFORMS & LOG. PALLETS
- SERVICE PROP'N & CAPSULE
- STOW PLATFORMS & PALLETS
- INSTALL DROP TANKS & LOAD CORE



- MOVE PROP'N UP TOWER
- ADD PAYLOAD
- C/O & SEPARATE

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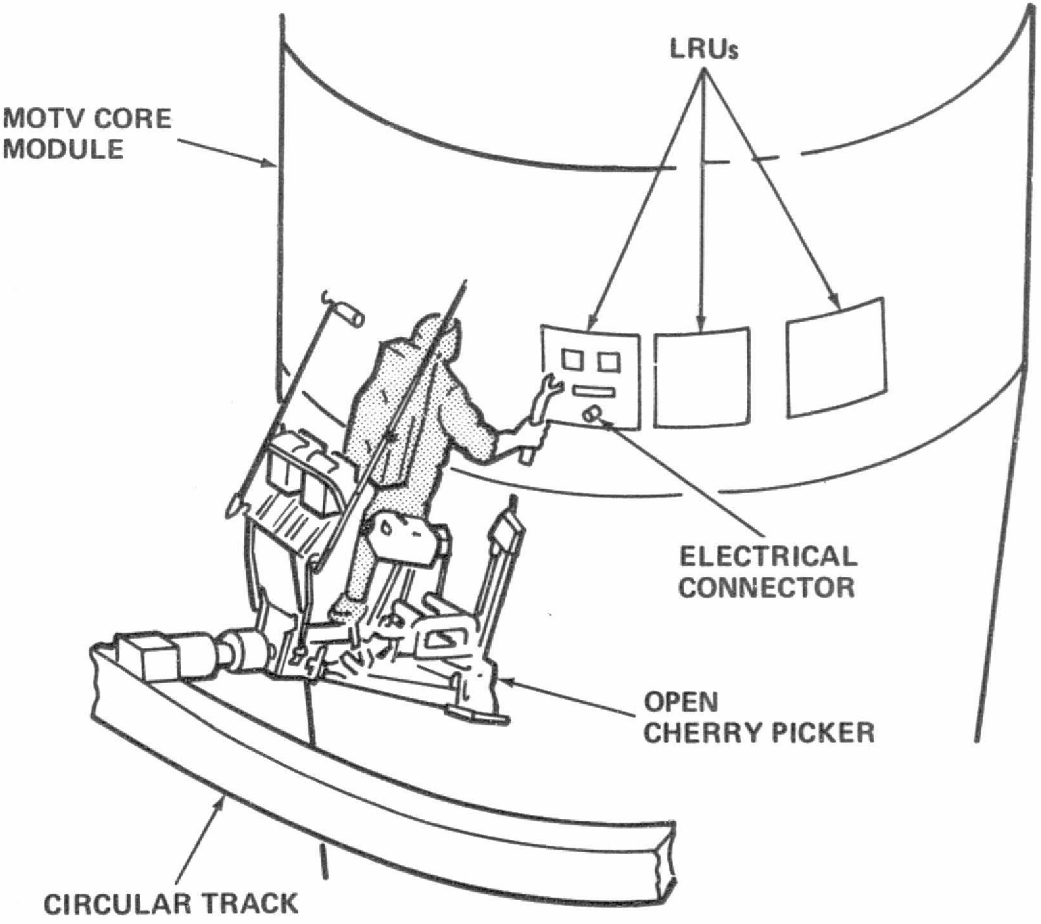
LRU REPLACEMENT EXTERNAL TO CORE MODULE

This illustration shows the EVA astroworker in position on the OCP ready to start removal of the electrical connectors using the special connector tool. The OCP is mounted on the service tower platform rail which has been positioned to facilitate the replacement task. The LRU is a multi-mission communications-band transmitter module.

MOTV SERVICE SCENARIO @ SOC
EVA SERVICING (SHT 3)

GRUMMAN



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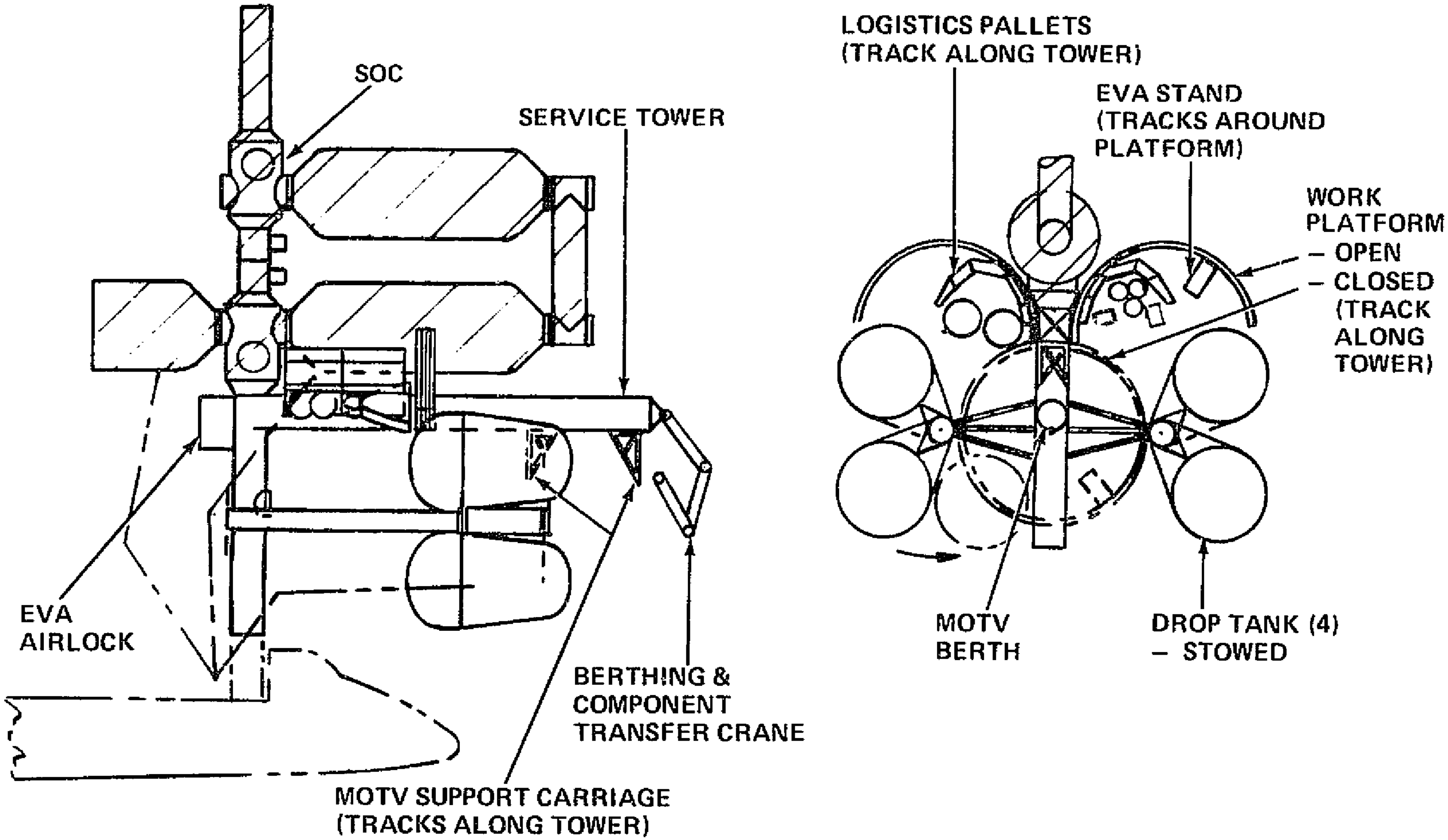
MOTV SERVICE FACILITY AT SOC - EVA SERVICING

To perform the tasks identified in the preceding MOTV servicing scenarios, this illustration shows a facility where the turnaround crew work EVA. The basic SOC is shown 'cross-hatched' to emphasize the added facilities. The tunnel to which the Orbiter docks on the standard SOC layout has been extended. A service tower has been added, attached to the tunnel, and running parallel to SOC habitation modules. This service tower has a series of tracks over its length along which carriages run to support the MOTV and position it where required, logistics pallets, and a series of work platforms which can be closed to surround the MOTV at appropriate levels. Each work platform has a traveling stand on which the EVA man moves around the workpiece. A crane mounts to the top of the tower, where it operates to berth the MOTV to the carriages and to provide the muscle to transfer components, such as engines, from logistics pallets to installation site. Outrigger structures from the tunnel support pylons which mount drop tanks on swing arms. The tanks can be brought up by the Shuttle while the MOTV is away on a mission, stowed clear of the work zone, then swung into mating position when required.

MOTV SERVICE FACILITY AT SOC
– EVA SERVICING

GRUMMAN



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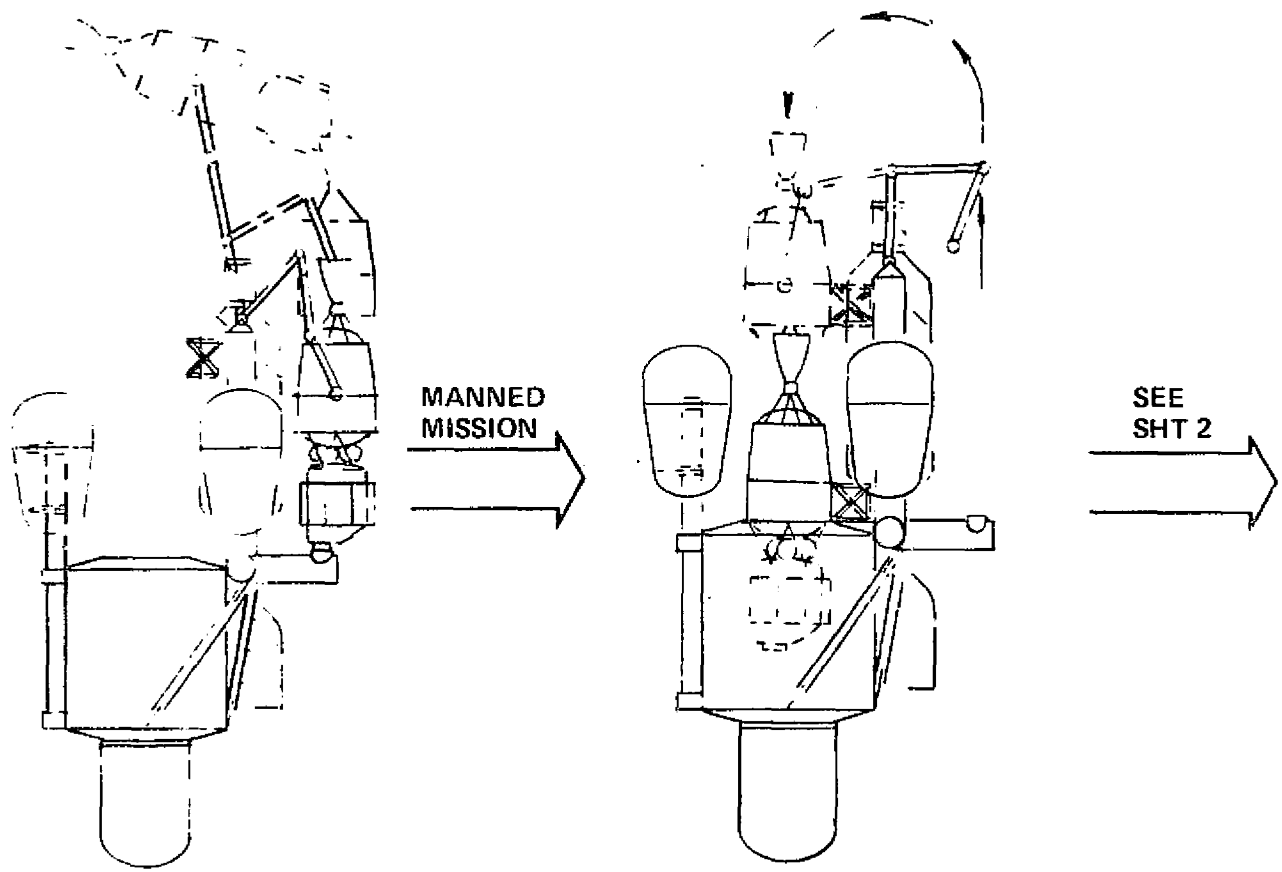
MOTV SERVICE SCENARIO AT SOC - SHIRTSLEEVE SERVICING (Sht 1)

This and the following illustration propose a scenario for servicing an MOTV at SOC using unsuited crewmen working in a pressurized atmosphere. The MOTV returns from a manned flight, is captured by a manipulator, and berthed to a pressurized part of SOC for the crew to disembark. Assuming that the next mission is also manned, the manipulator transfers the vehicle to a pressurizable hangar which accepts the crew capsule and its appendages. These are now serviced from work platforms in the hangar.

Referring to the following illustration (Sheet 2), the vehicle is raised from the hangar, rotated through 180° then lowered back into the hangar so that the propulsion subsystem concerned with the engines and the subsystems located between the propellant tanks are contained within the hangar. These subsystems are now serviced. On completion, the vehicle is again raised from the hangar, drop tanks are installed and propellant is transferred to the core. As presently envisaged, the MOTV crew boards a small capsule which is transferred by the manipulator to berth with the MOTV crew capsule. The crew then board the MOTV. The transfer capsule is removed, the vehicle systems checked out, then separated from SOC using the berthing manipulator to avoid possible fouling of SOC.

MOTV SERVICE SCENARIO AT SOC – SHIRTSLEEVE SERVICING (SHT 1)

GRUMMAN



- MOTV BERTHED
- CREW DISEMBARK

- MOTV TRANSFER TO HANGAR
- SERVICE CREW CAPSULE

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MOTV

MOTV SERVICE SCENARIO AT SOC – SHIRTSLEEVE SERVICING (SHT 2)

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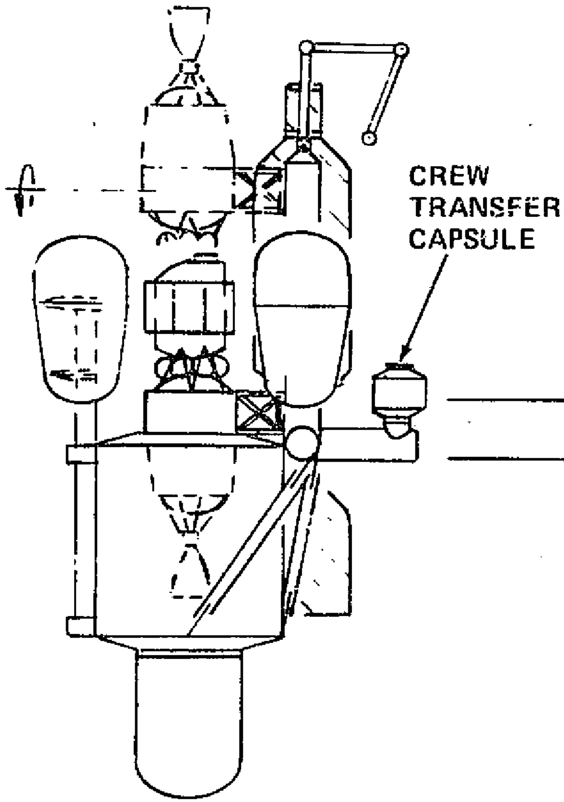
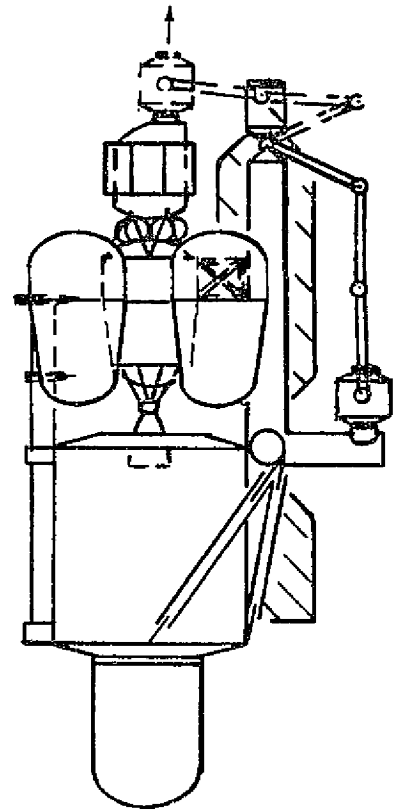


- RAISE FROM HANGAR
- ROTATE 180° & LOWER
- SERVICE PROP'N



- INSTALL DROP TANKS & LOAD CORE
- BOARD CREW
- C/O & SEPARATE

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MOTV SERVICE SCENARIO AT SOC - SHIRTSLEEVE SERVICING (Sht 3)

Considering preparation of an OTV for an unmanned mission, using shirtsleeved crewmen working at SOC, this scenario starts with the return of an MOTV from a manned mission, as described on a preceding illustration. Having disembarked the crew, propulsion core/crew capsule interfaces are released; then the core is transferred by the manipulator to be lowered into the pressurizable hangar, engines first. As with the preceding scenario, propulsion subsystems are serviced. The propulsion core is now raised out of the hangar, drop tanks are installed using the manipulator, with perhaps some EVA assistance and, in the same manner, the payload is installed.

After checkout, the vehicle is separated from SOC by the berthing manipulator.

MOTV SERVICE SCENARIO AT SOC – SHIRTSLEEVE SERVICING (SHT 3)

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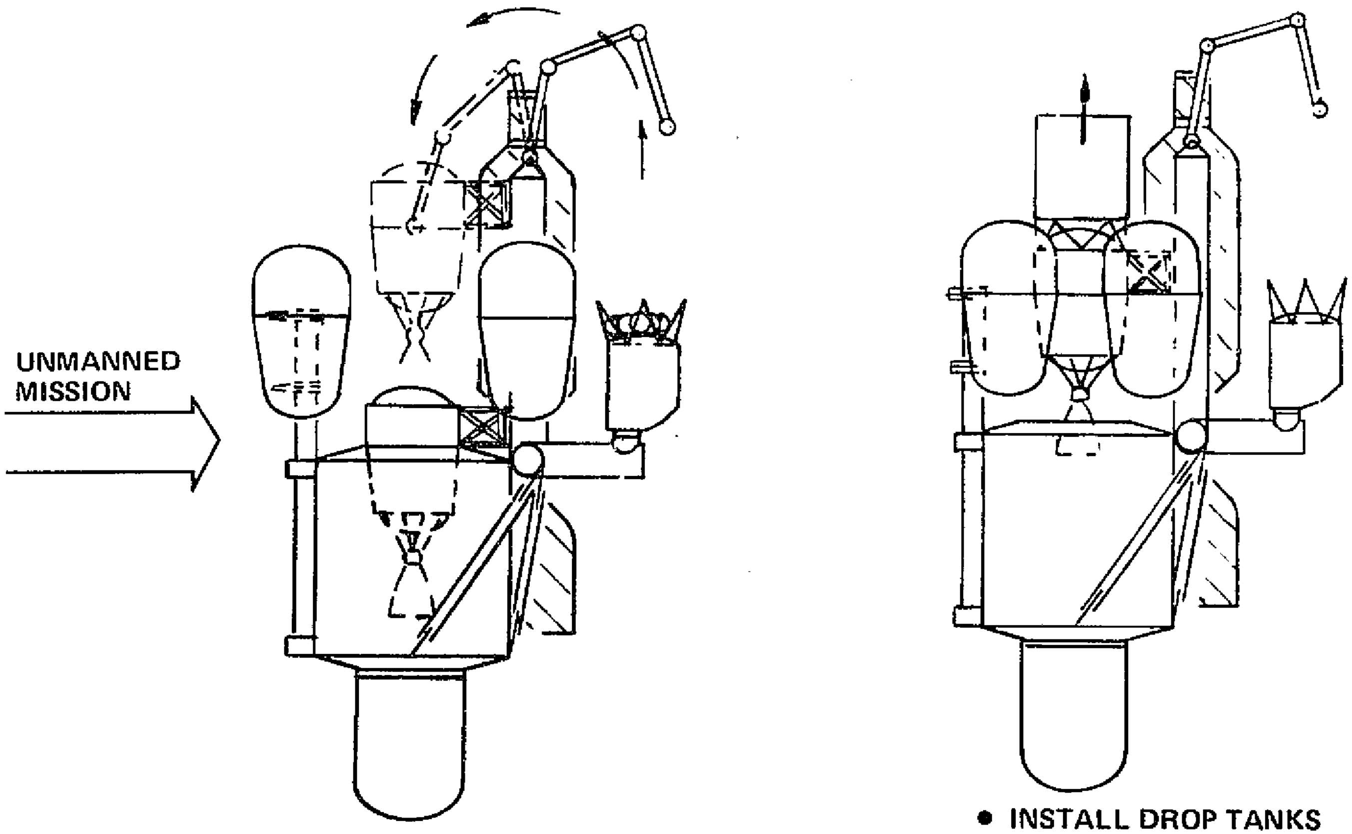

- SEPARATE PROP'N & TRANSFER TO HANGAR
- SERVICE PROP'N

- INSTALL DROP TANKS & LOAD CORE
- ADD PAYLOAD
- C/O & SEPARATE

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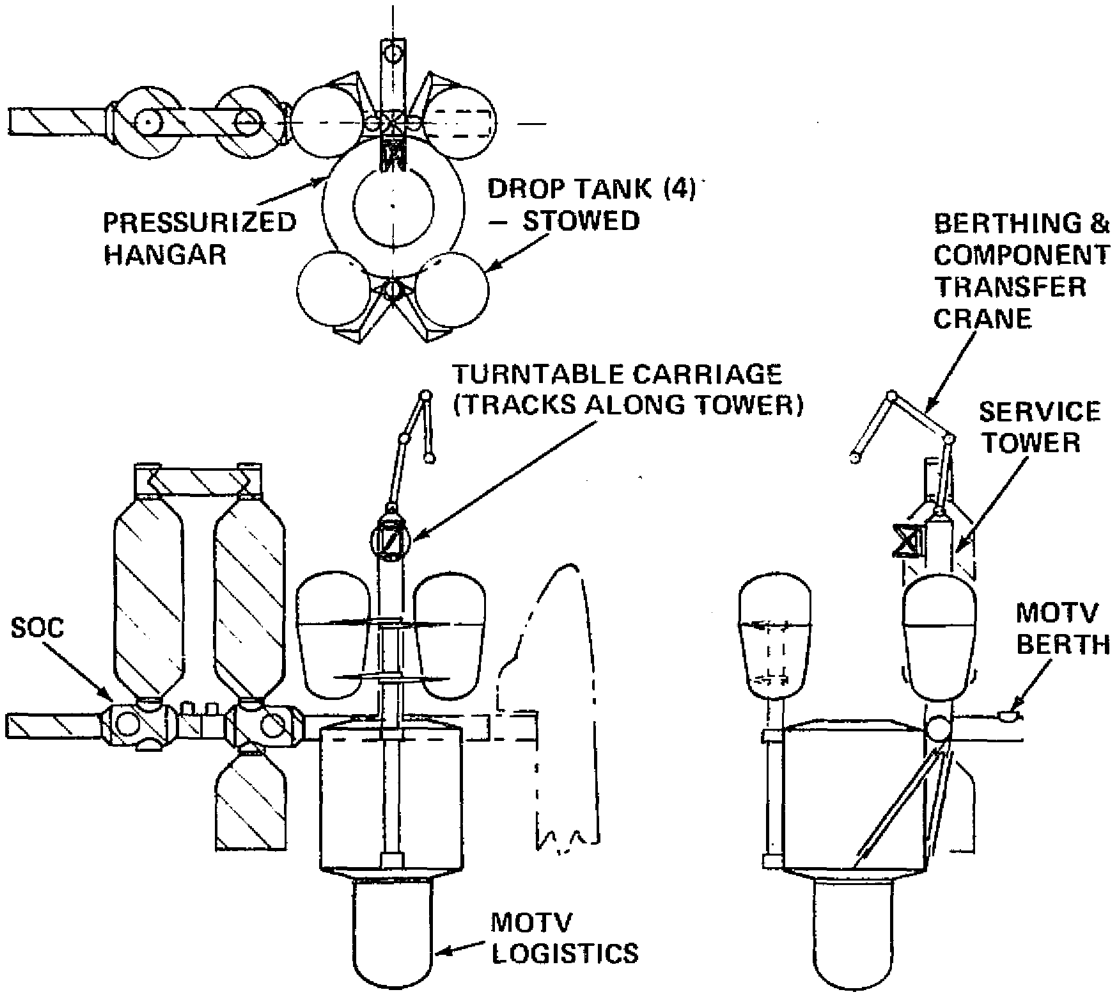
MOTV SERVICE SCENARIO AT SOC - SHIRTSLEEVE SERVICING

To perform tasks identified in the preceding 'shirtsleeve' scenarios, this illustration shows a facility where the turnaround crew work in a pressurizable hangar. It is similar in layout to the facility for EVA servicing except for the hangar. Logistics are now contained in a pressurized module which is docked to the hangar. Work platforms no longer run up the service tower; they are located inside the hangar.

MOTV SERVICE FACILITY AT SOC – SHIRTSLEEVE SERVICING

GRUMMAN



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MOTV TURNAROUND FUNCTIONAL REQUIREMENTS
GROUND VS SOC

The accompanying illustration shows the method used to develop the SOC turnaround requirements. Since we are earthbound in our thinking, we start with the ground requirements and manhours - in this case for scheduled maintenance. The ground baseline effort (manhours) are reduced for SOC by eliminating some tasks, reducing others and estimating the effect of improved SOC tools and MOTV SOC design. The results of this effort are ground equivalent SOC manhours broken down by IVA and EVA tasks. Actual SOC manhours are then computed by multiplying the ground equivalent SOC manhours by the appropriate factors which take into account the efficiency of man at LEO in performing the IVA and EVA tasks. These factors, 1.1 and 3 for IVA and EVA respectively, were specified in the groundrules for the trades. The total SOC LEO manhours are the sum of the calculated IVA and EVA manhours.

MOTV TURNAROUND FUNCTIONAL REQUIREMENTS – GROUND VS SOC

MOTV

GRUMMAN

SCHEDULED MAINTENANCE	GND M HR	REDUCED GND EQUIV. LEO M HR IVA	EVA	RATIONALE	LEO EQUIV M HR IVA X 1.1	EVA X 3	TOTAL
• SAFETY & DAMAGE INSP'TION (ALL SYS) – ECLSS - (RADIATORS, TNKS COMPONENTS) – ENGINES, RCS, PROPULSION SYS – EPS - FUEL CELLS, TNKS, PANELS, DISTRIB. – AVIONICS - NAV, COMM & DATA MGT COMPONENTS – CABIN - SYS COMPONENTS, CNTRLS & DISPLAYS – STRUCTURE (PRIMARY & SECONDARY) CREW & PROP MODULE – STS INTERFACES	84	18	42	• BETTER ACCESSIBILITY • SPECIAL EVA TOOLS • MOTV DESIGNED FOR SOC MAINTENANCE – OFI > CAPABILITY – LRUs > ACCESSIBILITY – LRUs SOC REPLACEABLE	20	126	146
• PERIODIC REPLACEMENT							
– ECLSS (FILTERS, PUMPS, TANKS)	28	10	4		11	12	23
– ENGINES, RCS & PROP	56	8	16	• DECREASE TASKS	9	48	57
– EPS (BATTERIES, COMPONENTS) – AVIONICS (TV LAMPS, IMV, COMM & TRK'G)	28	8	12	– LESS INSPECT'N PTS – MINIMUM REPLAC'NTS	9	36	45
– SENSORS REQ'G BENCH CAL	18	–	–	– OFF LINE CAL - NONE – NO ENGINE REPLACE'TS			
• SERVICE - ECLSS & EPS, RCS	48	10	12	– SUBSYS PERFORMANCE	11	36	47
• INPLACE CAL'S & SUBSYS, SYS & MISSION READINESS TESTS	96	40	16	TESTS ELIMINATED OR AUTOMATED	44	48	92

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RATIONALE FOR REDUCTION OF LEO MHR
(GND EQUIVALENT LEO MHR)

This illustration lists the rationale used to reduce the ground based manhours for the comparable SOC tasks. The first step was to either eliminate or reduce the number of SOC maintenance tasks, especially labor intensive tasks and, in particular, those requiring EVA. The SOC ground equivalent effort was further reduced by postulating the effect of special SOC tools and MOTV maintainability features. Depending on the specific tasks, the SOC and MOTV design features averaged between 10 - 20% reduction in SOC ground equivalent manhours.

RATIONALE FOR REDUCTION OF LEO M HR – (GND EQUIVALENT M HR)

GRUMMAN

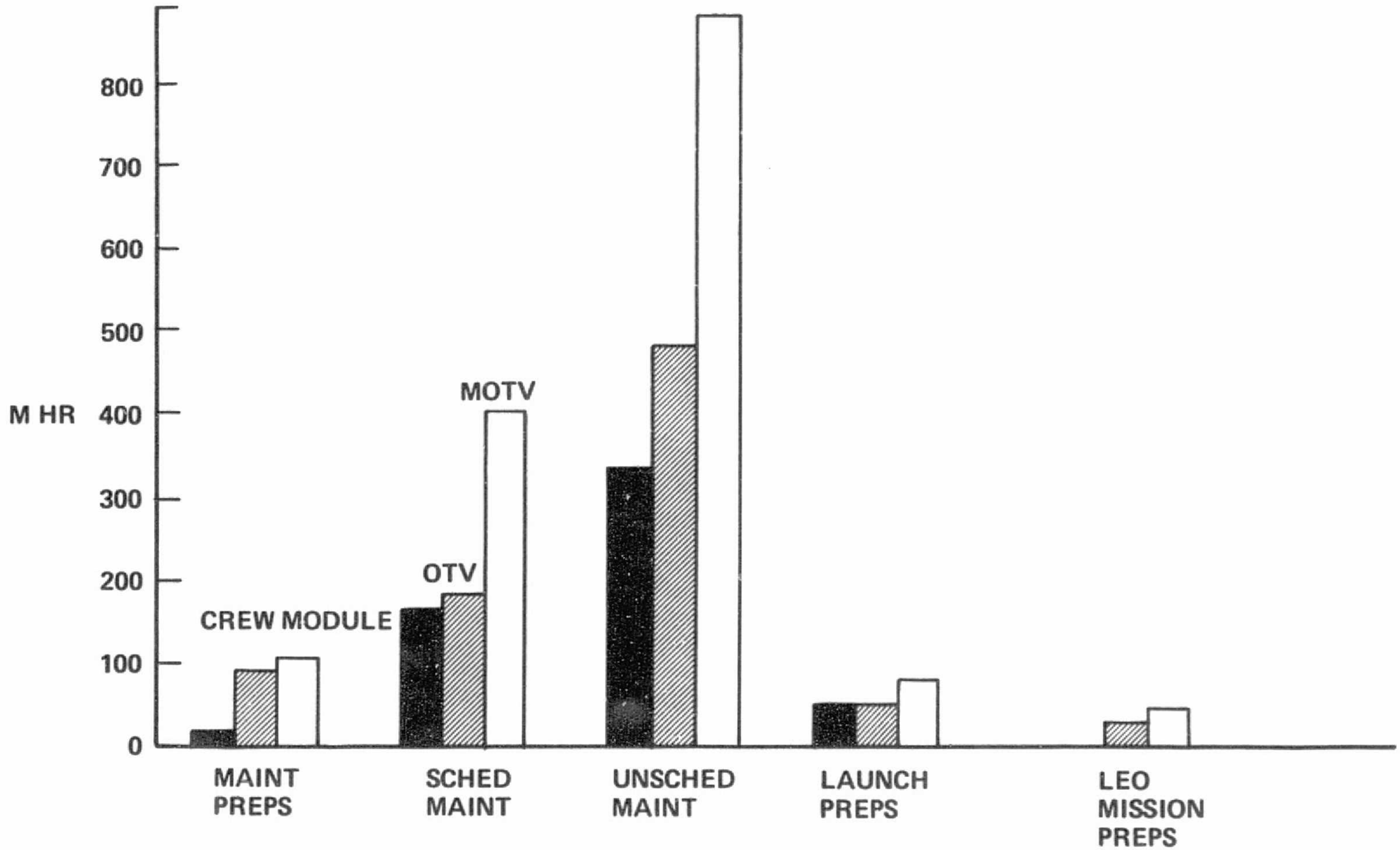
- REDUCE NO. OF SOC TASKS
  - LABOR INTENSIVE
  - EVA REQD
- SPECIAL SOC DESIGNED EQUIPMENT
  - OCP, MANIPULATORS, TURNTABLES, ETC.
  - HAND TOOLS, WORK RESTRAINTS
- MOTV DESIGNED FOR SOC MAINTENANCE
  - INCREASED OFI CAPABILITY
  - LRU SOC REPLACEABLE
  - ACCESSIBILITY INCREASED

VEHICLE CONFIGURATION, OPTION 1, RESULTS FOR

GROUND TURNAROUND BASELINE

The accompanying illustration indicates the variation in manhours as a function of vehicle configuration for the ground turnaround baseline. The core propulsion module requires more manhours than the crew because it contains more equipment and requires more mechanical type of operations than the crew module. In calculating maintenance preparation manhours all of the handling, transportation and demate tasks were charged against the core propulsion module or the complete core crew module combination. The approximately 15 manhours required to prepare the crew module are for swinging it into its workstand and adjusting the work platforms. Since the crew module never flies alone to LEO, there were no crew module mission preparations.

VEHICLE CONFIGURATION – OPTION 1 RESULTS FOR GROUND TURNAROUND (OVERHAUL)

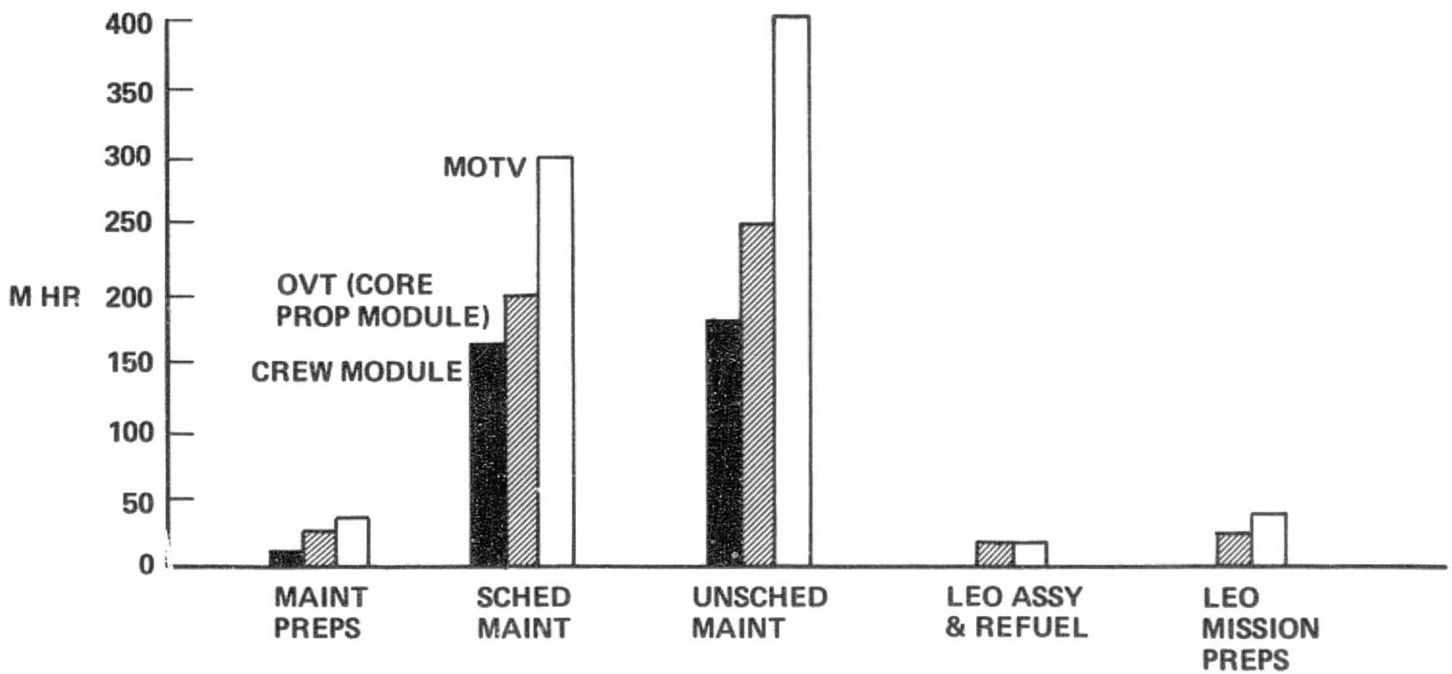


VEHICLE CONFIGURATION, OPTION 1, RESULTS FOR SOC PERIODIC MAINTENANCE

The accompanying illustration shows the same trend for turnaround of the various modules configurations at SOC as on the ground (shown on the previous illustration). The crew module SOC operations are further reduced because it is not involved in LEO assembly and refueling operations as well as final mission preparations.

VEHICLE CONFIGURATION – OPTION 1 FOR SOC PERIODIC MAINTENANCE

GRUMMAN



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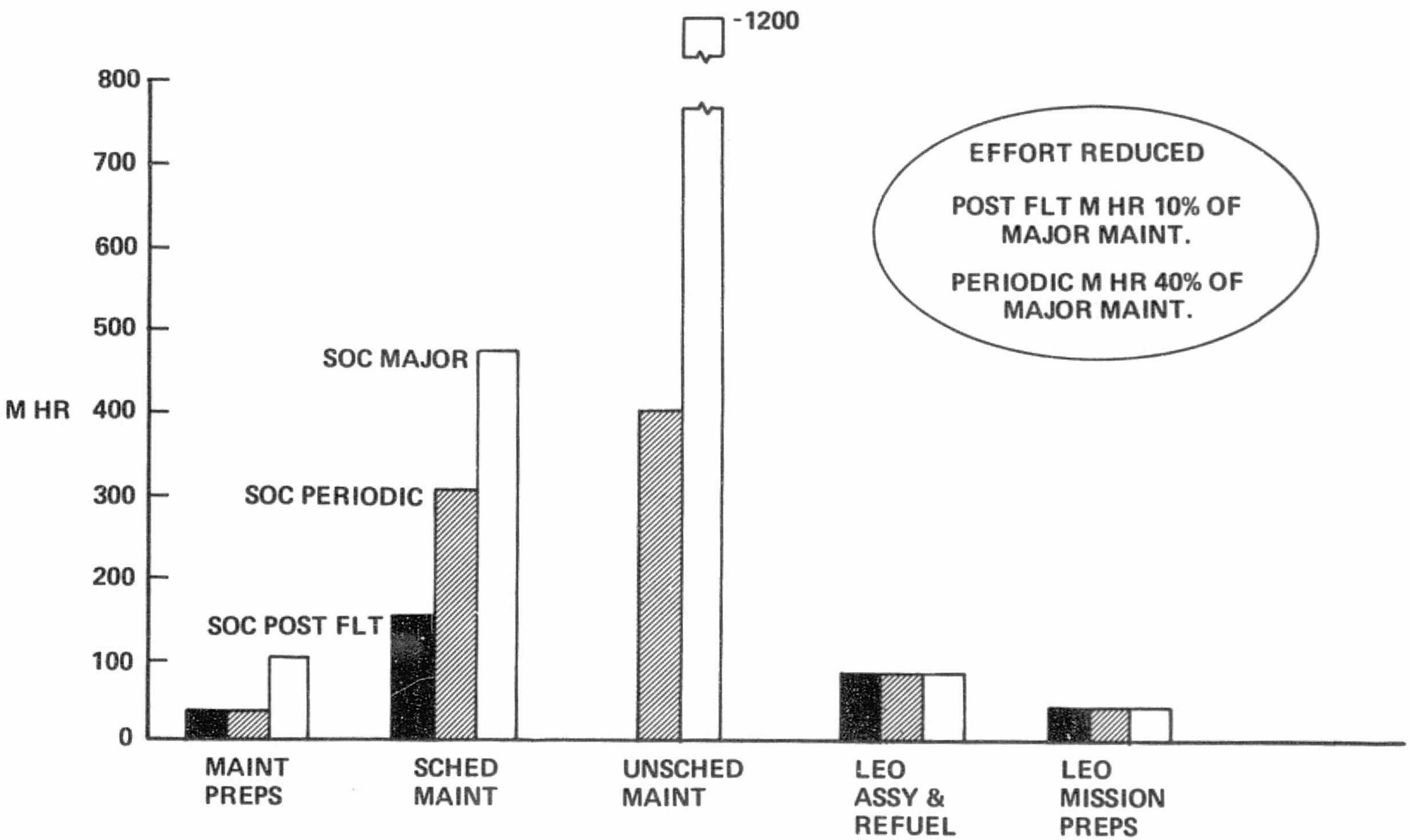
VARIATION IN AMOUNT OF MAINTENANCE, OPTION 2, FOR MOTV

The accompanying illustration shows the reduction in effort possible for the various levels of maintenance at SOC. Post flight, which essentially is for a vehicle which returns with flight data indicating all systems are go, is subjected to safety and damage inspection which does not turn up any problems, and is then serviced and is ready for the next flight. This basically "gas and go" turnaround is 10% of the effort required for a fairly complete maintenance effort as postulated in our basic study. Periodic maintenance is accomplished approximately every 4th flight and includes replacement of a couple of defective LRUs, batteries or easily accessible filters; calibration of selected hardware would take approximately 40% of full-up effort. The major or full-up effort reflects our baseline data which postulated a fairly independent SOC which could accommodate a fairly major maintenance effort conducted after approximately 8 flights to dispel any gnawing concerns that had been put on the back burner and could simultaneously accommodate modest modification of the vehicle. This major effort would include performance checks of all subsystems.

VARIATION IN AMOUNT OF MAINTENANCE – OPTION 2 FOR MOTV



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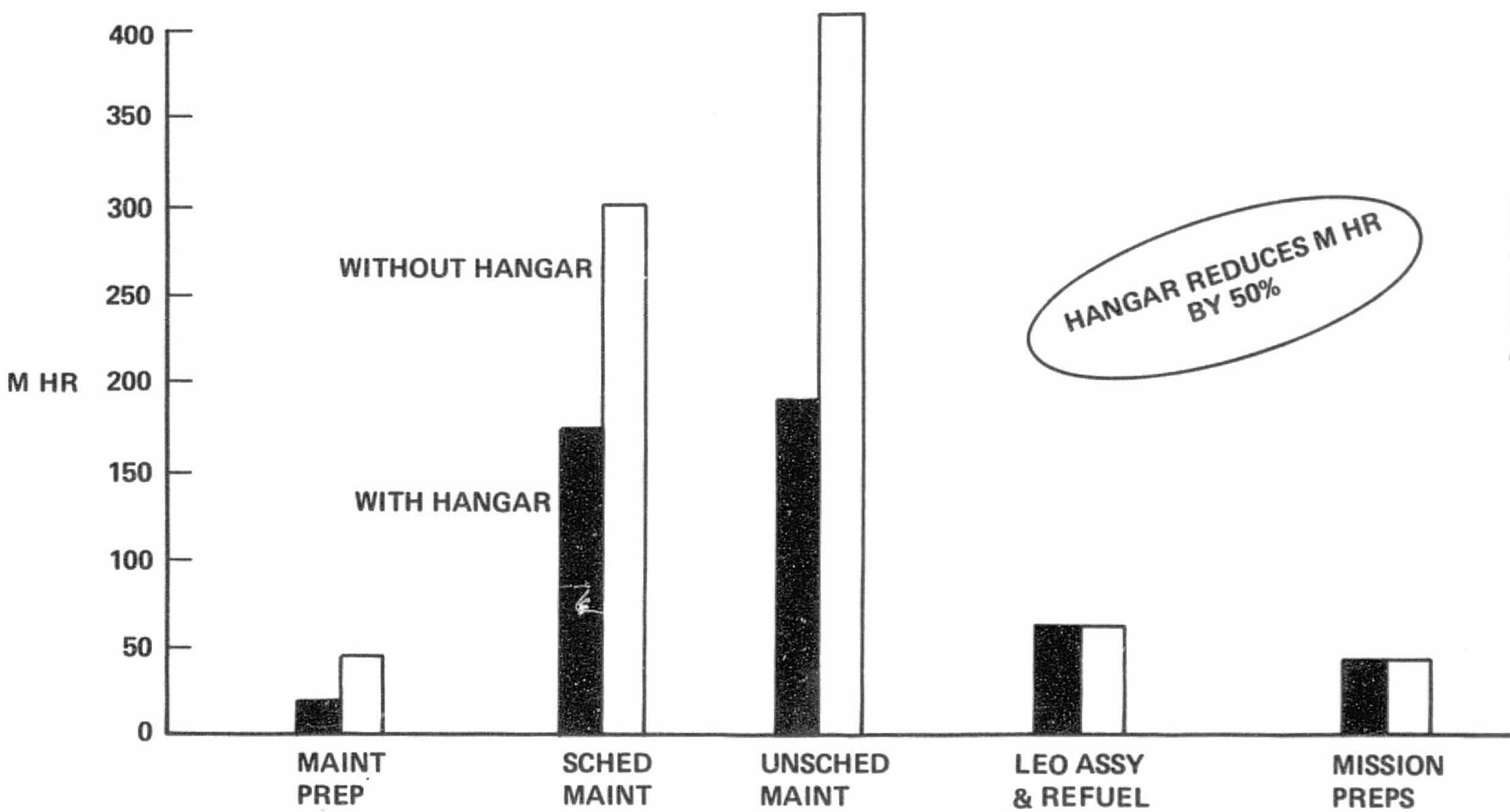
PRESSURIZED HANGAR, OPTION 3, FOR MOTV PERIODIC MAINTENANCE

This illustration shows the effect on manhours of a pressurized maintenance hangar at SOC. Although the illustration shows the results for MOTV configuration, the trends are applicable to the other configurations. As indicated, the pressurized hangar reduces the manhours significantly - approximately 50%. The reduction reflects the efficiency of the IVA vs the EVA astroworker to accomplish tasks at LEO. Since manpower costs are a recurring operational liability, the pressurized hangar is a viable consideration for SOC which should be further investigated. The next illustration looks at the operational costs of the pressurized hangar option.

PRESSURIZED HANGAR-OPTION 3 FOR MOTV PERIODIC MAINTENANCE



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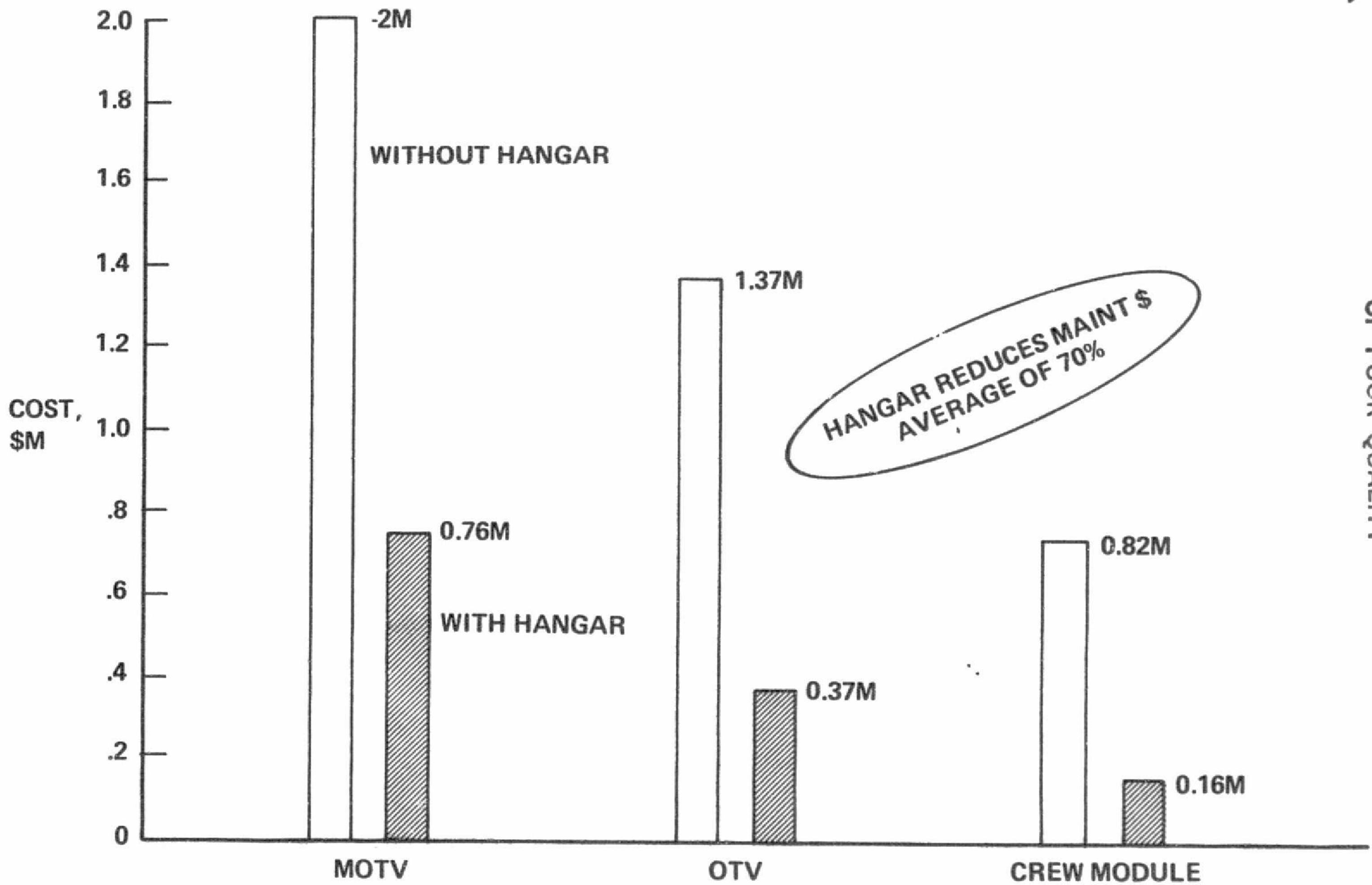
SOC TURNAROUND PERIODIC MAINTENANCE COSTS FOR OPTION 3
PRESSURIZED HANGAR, OPTION 3

This illustration shows the total recurring SOC operational labor costs with and without the pressurized hangar for each configuration (MOTV, OTV and crew module). On the average, among the three configurations, there is a savings of approximately 70% in recurring operational labor costs. This increase of 20% in costs over the 50% in manhours shown on the previous illustration reflects the coupling efficiency and cost of SOC IVA vs EVA operations. This illustration further substantiates the viability of a pressurized hangar for OTV/MOTV turnaround operations.

SOC TURNAROUND PERIODIC MAINTENANCE COSTS FOR OPTION 3 PRESSURIZED HANGAR

GRUMMAN



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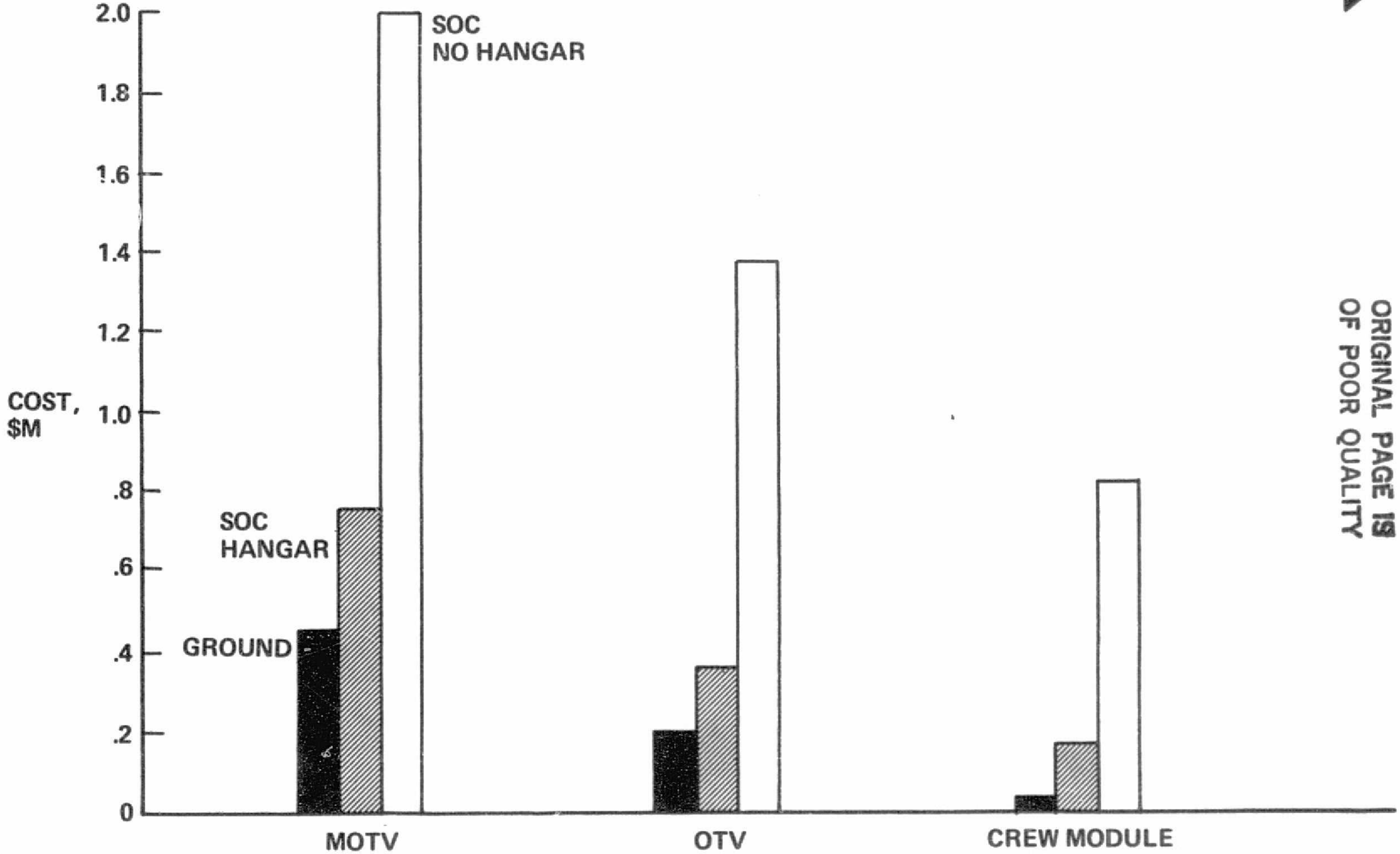
SUMMARY - OPTIONS 1 AND 3 TURNAROUND COSTS

The accompanying illustration combines, in summary fashion, the evaluation of options 1 and 3, configuration and pressurized hangar, options. The costs were calculated on the basis of a periodic maintenance effort at SOC vs a major overhaul effort on the ground. These two maintenance levels were selected for comparison because they typify the level of activity which would be accomplished at each maintenance base. It reflects the trends described in the previous illustrations and shows that a pressurized hangar environment brings the operational labor costs of ground and SOC within 40% of each other.

OPTIONS 1 & 3 TURNAROUND COSTS



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CONFIGURATION COST TRADE
SOC MOTV HANGAR

The facing page presents the results of a configuration cost trade for the SOC MOTV Hangar. The trade was made to evaluate the effect of hangar volume as a function of length on cost.

In configuration A, the hangar is 330 in. in diameter and 330 in. in length. This configuration permits SOC space-workers to perform MOTV maintenance in a shirt-sleeve environment over approximately 50% of the MOTV. Work on the other half of the MOTV in a shirt-sleeve environment would require hangar depressurization, MOTV rotation and hangar repressurization.

Configuration B is also 330 in. in diameter but is 660 in. in length. This permits complete MOTV maintenance in a shirt-sleeve environment without depressurization, MOTV rotation and hangar repressurization.

The cost trade considered hangar DDT&E, Production, Transportation to low earth orbit and assembly in space. The assembly in space costs were derived using NASA/JSC provided EVA cost rates. Transportation costs are based on the STS User Guide. DDT&E and Production costs are provided by Grumman CERs. The cost trade indicates that approximately $32M, in 1979 dollars, are required to provide the capability for one-position shirt-sleeve maintenance of the MOTV.

MOTV

CONFIGURATION COST TRADE
SOC MOTV HANGAR

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COST ELEMENT	COST	
	CONFIG A	CONFIG B
HANGAR DDT & E	78.6	98.0
HANGAR PRODUCTION	10.5	15.3
STS TRANSPORTATION	16.0	23.8
SPACE ASSEMBLY	0.53	0.9
TOTAL	$105.6M	$138.0M

GRUMMAN

MOTV TURNAROUND ANALYSIS

GRUMMAN

BACKGROUND DATA

SOC/GND TURNAROUND ANALYSIS

RECOMMENDED SOC/GND MIX & SUPPORT REQMTS

CONCLUSIONS

OTV/MOTV 5-YEAR PROJECTED TRAFFIC & RECOMMENDED SOC/GND TURNAROUND MIX

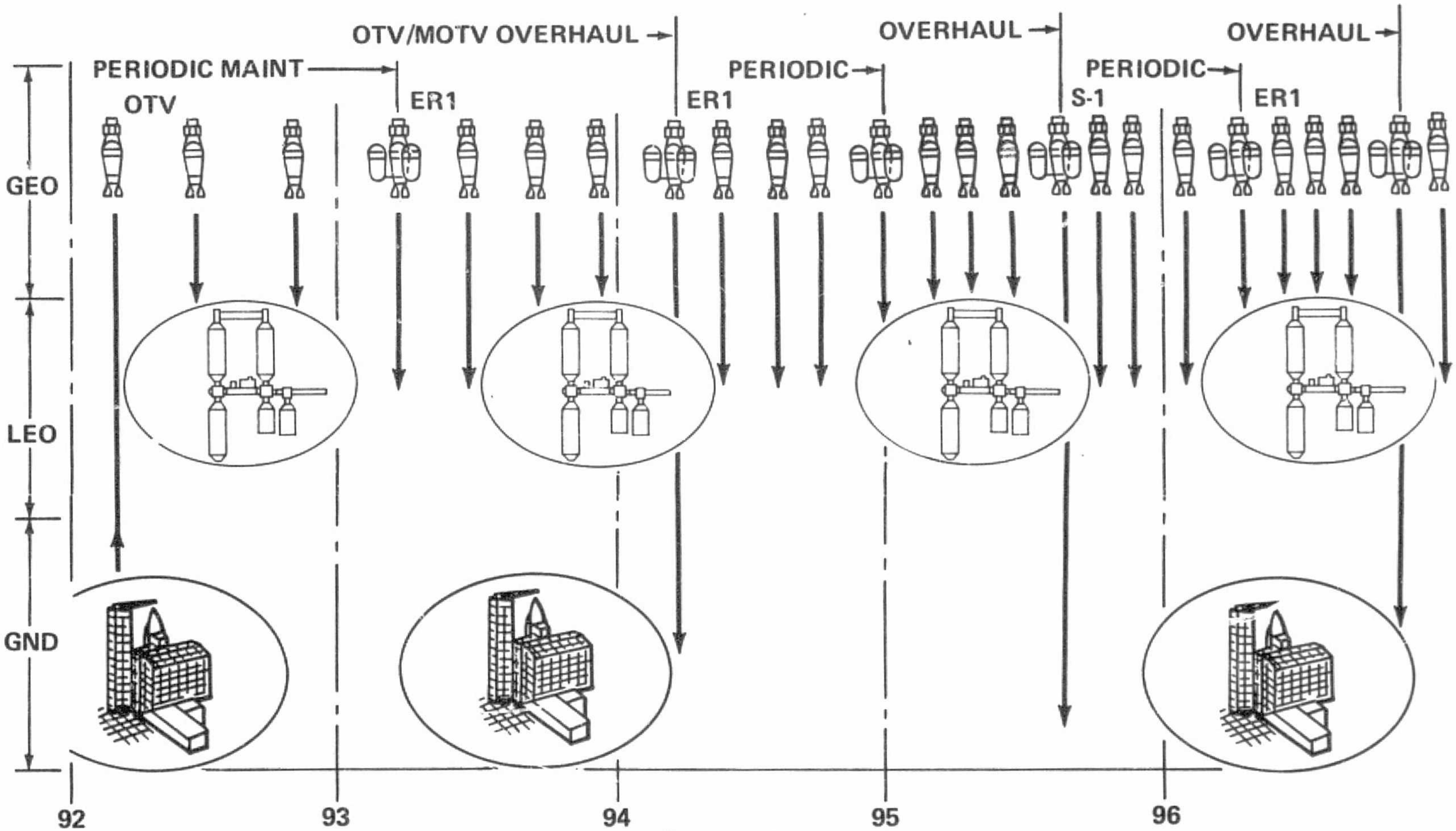
The accompanying illustration translates some of the conclusions reached during our study of the various options to a projected traffic scenario. Operationally, it answers the question, "How would we expect to handle the projected OTV/MOTV flights?" The traffic scenario assumes a 1992 IOC; a 3/1 ratio of OTV to MOTV flights and a 3/1 ratio of long duration (S-1 type) to short duration missions (ER1 type); and a gradual build-up from 3 to 6 flights in 4 years. For this scenario we propose to perform:

- Post Flight (PF) Only - Safety & damage inspection, service and go - on every flight at SOC
- Periodic - PF plus limited maintenance - on every fourth flight at SOC
- Overhaul - Complete inspection, performance checks, calibration of sensors, change out of limited life (include engine) and sensors - on the ground

This mix of SOC/GND turnaround activities is recommended because it makes use of SOC for routine and non-labor intensive tasks to reduce the degree of shuttle support required.

MOTV/OTV 5-YEAR PROJECTED TRAFFIC & TURNAROUND MAINTENANCE CYCLES

GRUMMAN



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TRANSPORTATION, MECHANICAL, FLUIDS SUPPORT EQUIPMENT REQUIREMENTS FOR GND/SOC TURNAROUND MIX

The accompanying illustration shows the type of transportation, mechanical and fluid we believe would be required to support the proposed SOC/GND maintenance activities shown on the previous illustration. It shows a significant drop in the use of transportation and mechanical equipment required at SOC. The reduction in this type of equipment is possible because of the reduction in handling and other mechanical activity in SOC, plus the incorporation of SOC facility capability for related functions.

TRANSPORTATION, MECHANICAL, FLUIDS TRANSPORTATION SUPPORT EQUIPMENT REQMTS – GND & SOC TURNAROUND

GRUMMAN

SUPPORT EQUIPMENT	GND	SOC
● TRANSPORTATION		
1) DROP TANK TRANSPORTERS (2)	X	
2) DROP TANK ENVIRONMENTAL COVERS (2)	X	
3) DROP TANK SHIPPING CONTAINERS (2)	X	
4) TRANSPORTATION TIEDOWN SET	X	
5) TRANSPORTER COOLING & PRESS. UNIT (3)	X	
6) CORE MODULE TRANSPORTER	X	
7) CORE MODULE ENVIRONMENTAL COVER	X	
8) CORE MODULE SHIPPING CONTAINER	X	
● MECHANICAL	X	
1) MOTV & INDEXED TURNTABLE		X
2) MOTV, PROP CORE, CREW MOD & TNK HANDLG. FIXTURE	X	X
3) CREW COMPARTMENT SLING	X	X
4) DROP TANK/CORE MODULE SLING SET	X	
5) DROP TANK SUPPORT RINGS (2)	X	X
6) WORKSTANDS – DROP TANK/CORE CREW MODULE	X	X
7) ENGINE DOLLY (2)	X	
8) ENGINE INSTALLATION TOOLS	X	
9) MODULE INSTALLATION FIXTURES (4)	X	
10) INTEGRATED ASSEMBLY WORKSTAND	X	
11) CORE MODULE SUPPORT RING	X	X
12) ENGINE THROAT PLUGS (2)	X	
13) PYRO SIMULATOR SET (1)	X	X
14) SOLAR ARRAY INSTALLATION TOOL	X	
15) SOLAR ARRAY DEPLOYMENT FIXTURE	X	
16) LRU SOC REPLACEMENT TOOLS		X
17) INSPECTION TOOLS	X	X

FLUID SUPPORT EQUIPMENT	GND	SOC
1) CABIN AIR SUPPLY UNIT (800 + 800 = 1600 x 35)	X	X
2) COOLING UNIT	X	X
3) CABIN LEAK TEST UNIT	X	X
4) ECLSS CHECKOUT CART (1100 + 1000)	X	X
5) GOX SERVICE UNIT	X	X
6) GN_2 SERVICE UNIT	X	X
7) N_2 PURGE SYSTEM	X	X
8) CYRO SYSTEMS C/O UNIT	X	
9) WATER STORAGE & TRANSFER UNIT	X	X
10) GOX SYSTEM VACUUM PUMP	X	X
11) WATER SYSTEM VACUUM PUMP	X	X
12) LEAK DETECTOR CART	X	X
13) PROPULSION SYSTEM C/O UNIT	X	X
14) HELIUM PRESSURIZATION UNIT	X	X
15) PURGE & DRYING CART	X	X
16) FUEL CELL VACUUM PUMP	X	X
17) FUEL CELL SERVICING UNIT	X	X
18) WASTE MGMT SYST SERVICING UNIT	X	X
19) Q.D./FILTER SET	X	X

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AVIONICS SUPPORT EQUIPMENT REQUIREMENTS FOR GND & SOC TURNAROUND MIX

This depiction illustrates the kind of avionics support equipment required to support the proposed SOC/GND activities. The significant reduction in SOC equipment is based on the absence of detailed calibrations and performance tests conducted at SOC and the assumption that the vehicle Operational Flight Instrumentation System (OFIS) can check the health and status of all subsystems and identify inoperable LRUs.

MOTV

AVIONICS SUPPORT EQUIPMENT REQMTS – GND & SOC TURNAROUND

GRUMMAN

SUPPORT EQUIPMENT	GROUND BASED	SOC
1) CAUTION & WARNING ELECTRONIC ASSEMBLY STIMULI GENERATOR	X	
2) RENDEZVOUS RADAR TEST BENCH	X	X
3) ATTITUDE CONTROL & DETERMINATION TEST STATION	X	
4) COMMUNICATION CHECKOUT & MAINTENANCE TEST STATION	X	
5) AUDIO CENTER TEST STATION	X	
6) DISPLAY & CONTROL CONSOLE	X	
7) PULSE CODE MODULATION & TIMING EQUIPMENT	X	
8) INSTRUMENTATION STIMULI GENERATOR	X	X
9) S/C STATUS ACQUISITION SYSTEM	X	
10) TV SYSTEM TEST SET	X	
11) S-BAND UPLINK AND DOWNLINK TEST SET	X	X
12) S-BAND, X-BAND, KU-BAND ANTENNA MAINT TEST STATION	X	
13) DISPLAYS & CONTROL MAINTENANCE TEST STATION	X	
14) PRN RANGING TEST SET	X	
15) X-BAND DOWNLINK DATA TEST SET	X	
16) DC TRANSIENT VOLTAGE POWER SUPPLY	X	

SUPPORT EQUIPMENT	GROUND BASED	SOC
17) CONSTANT CURRENT BATTERY CHARGER	X	
18) INVERTER SIMULATOR	X	
19) ELECTRICAL LOAD SIMULATOR	X	
20) VEHICLE GROUND POWER SUPPLY	X	X
21) BATTERY MAINTENANCE TEST STATION	X	
22) ENVIRONMENTAL CONTROL SYSTEM TEST STATION	X	X
23) REACTION CONTROL S/S CONTROL STATION	X	
24) HELIUM PRESSURIZATION CONTROL UNIT	X	X
25) RCS PRESSURIZATION CONTROL STATION	X	
26) RCS FIRING CONTROL STATION	X	
27) MAIN PROPULSION ELECTRICAL TEST SET	X	X
28) DIAGNOSTIC AUTOMATED TEST COMPUTER		
29) DIAGNOSTIC COMPUTER DISPLAY		
30) COMPUTER KEYBOARD CALL-UP		
31) POWER SOURCES SIMULATOR		
32) BATTERY CHECKOUT TEST/ DIAGNOSTIC STATION		

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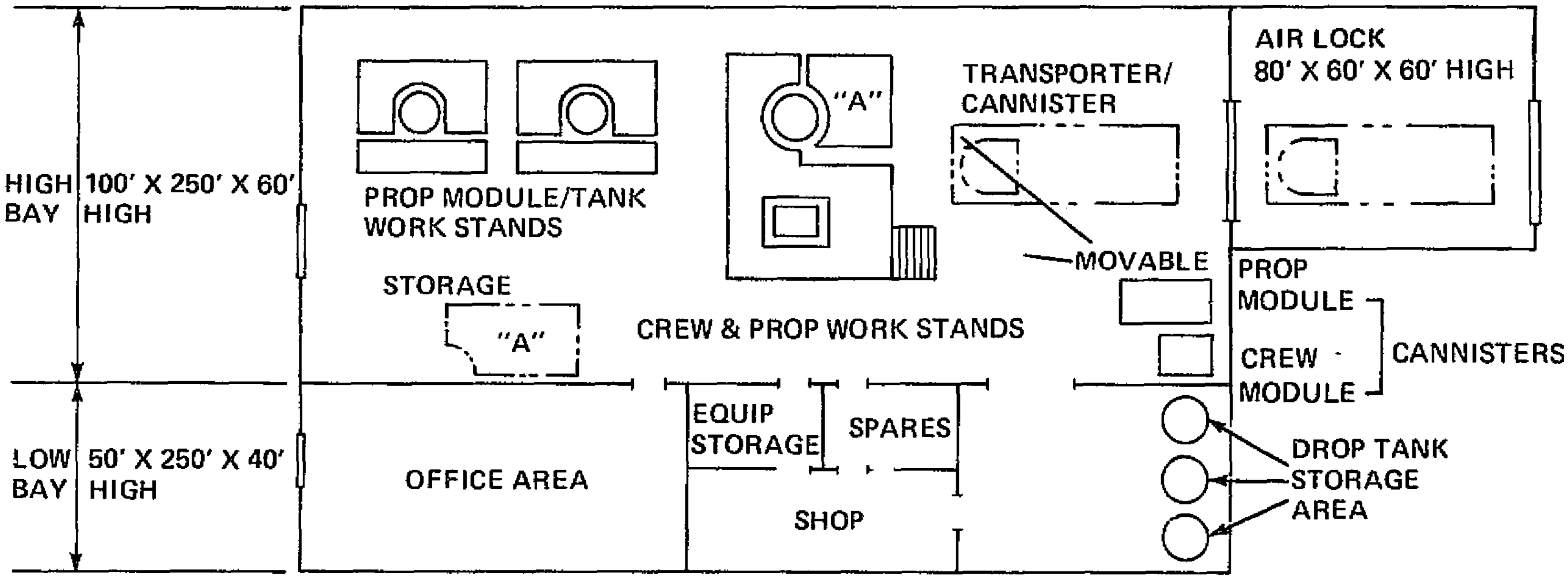
OTV/MOTV GROUND PROCESSING FACILITY

The accompanying layout shows the type of OTV/MOTV processing facility required at KSC. It contains a 60 ft high bay area with a 100,000 cleanliness level. The high bay must have two adjacent work stands (one horizontal and one vertical), an air lock for receiving and cleaning the modules prior to bringing them into the work area, and room to store movable work platform, drop tanks and transportation cannisters. Also included are two additional work stands which can be used for either propulsion core or drop tank module maintenance. The low bay area provides equipment and logistics stowage and shop and office space.

OTV/MOTV GROUND MAINTENANCE C/C & INTEGRATION FACILITY

GRUMMAN



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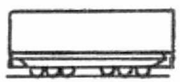
GROUND TURNAROUND (OVERHAUL) HANDLING & TRANSPORTATION REQUIREMENTS

The accompanying illustration shows the ground handling and transportation requirements during overhaul and maintenance operations at KSC. The OTV/MOTV configuration is removed from the Orbiter at the Orbiter Processing Facility (OPF) in the horizontal position. It is placed in the KSC standard payload cannister/transporter and, if an MOTV is being processed, it is demated while in the horizontal attitude. The crew module is placed in a horizontal workstand which better orients the crew compartment for maintenance purposes. The core propulsion module is placed in a vertical workstand for maintenance. Following extensive mods it may be necessary to recheck the drop tank-to-core interfaces which would be accomplished in the core workstand. The crew module and core modules are colocated so that a complete checkout of the MOTV functional interfaces can be accomplished with interface extender cables from the crew module. For the MOTV mission, once the maintenance phase is complete and the mission readiness tests indicate both modules are "go", the modules are shipped individually on contractor-provided containers to the Vertical Processing Facility (VPF). The modules would be mated and all intermodule and STS interfaces checked out in one of the VPFs Cargo Integration Test Equipment (CITE) workstands. The complete vertically oriented cargo would be removed by the payload handling mechanism, put in the standard KS P/C cannister and shipped to the pad. At the pad the Payload Ground Handling Mechanism (PGHM) and the Rotating Service Structure (RSS) would be used to service the MOTV. Fueling of the MOTV would be accomplished in parallel with the STS fueling.

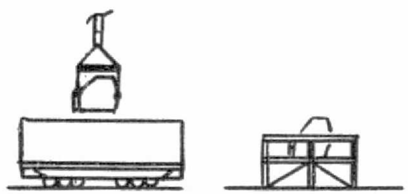
GROUND TURNAROUND HANDLING & TRANSPORTATION REQUIREMENTS

MOTV

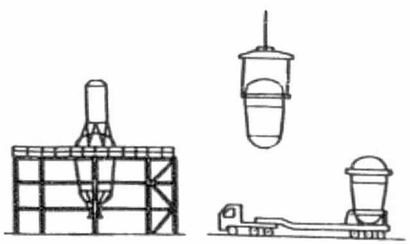
GRUMMAN



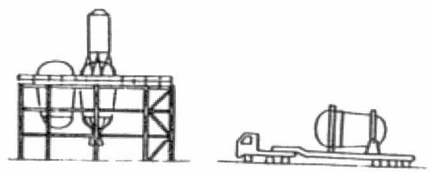
DELIVER CORE MANNED MODULE
(CCM) TO OTV/MOTV FACILITY.
CANNISTER IN HORIZONTAL POSITION



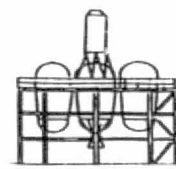
REMOVE CREW MODULE FROM CANNISTER
& MOVE TO HORIZONTAL STAND



INSTALL PROP MODULE IN VERTICAL STAND
DELIVER FIRST DROP TANK,
ROTATE TO VERTICAL, & TRANSFER TO STAND



DELIVER SECOND DROP TANK



TRANSFER SECOND DROP
TANK TO WORKSTAND &
CONDUCT INTEGRATED CHECKOUT

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KSC MOTV PAYLOAD PROCESSING FACILITY

MOTV processing at an operational site such as KSC will require a good-sized facility for overall MOTV overhaul; i.e., checkout, ground maintenance and integration. For preliminary planning purposes, a separate MOTV processing facility layout was prepared and costed as shown on the facing page.

This facility requires 3 operational areas. One is a high bay work area requiring a Class 100,000 clean room which is 100 ft x 250 ft in area and 60 ft high. It provides the operating volume for a horizontal Crew Module Processing workstand, Vertical Tank Module workstand and an OTV/MOTV integrated workstand. The second area in this facility is an Air Lock 80 ft x 60 ft in area and 60 ft high. The third area is a low bay office, shop and storage complex. It is 50 ft x 250 ft in area and 40 ft high.

The MOTV processing facility, as new construction, is estimated to cost \$3.6M in 1979 dollars.

KSC MOTV PROCESSING FACILITY

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FUNCTION	COST
HIGH BAY CLEAN AREA	2.5
AIR LOCK	.48
OFFICE/STORAGE AREA	.63
TOTAL	$3.61M

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SUPPORT EQUIPMENT COSTS - GROUND & SOC

The accompanying illustration lists the estimated costs for support equipment for the proposed ground and SOC turnaround mix. Although the number of support equipments required to support the proposed SOC activities were reduced by 60% as compared to the support equipment required to support the ground activities, the cost of the SOC support equipment was an order of magnitude greater. This is due to the need to redesign and qualify available ground support equipment for the space environment. In turn, this illustrates the need to minimize the SOC support equipment requirements.

SUPPORT EQUIPMENT COSTS – GROUND/SOC

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	GROUND UNITS	GROUND COST
FLUID SERVICING & C/O	22	95,000
TRANSPORTATION	13	85,000
MECHANICAL	20	62,000
ELECTRICAL C/O & DIAGNOSTIC	27	110,000
		252,000

	SOC UNITS	SOC COST
FLUID SERVICING & C/O	16	500,000
TRANSPORTATION	0	–
MECHANICAL	8	550,000
AVIONICS	6	200,000
		1,250,000

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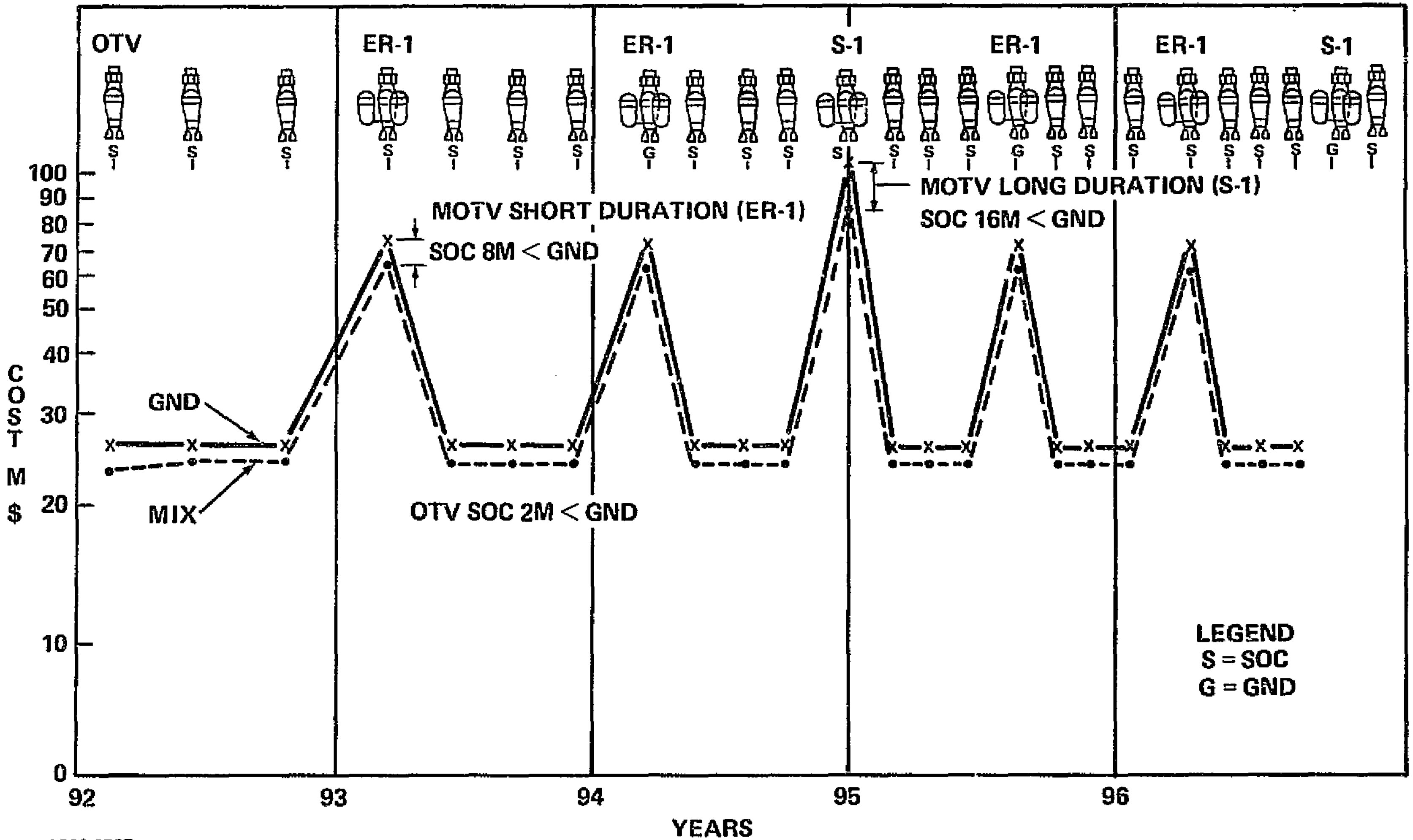
COMPARISON OF TOTAL MISSION TURNAROUND COSTS FOR GND BASED VS PROPOSED GND/SOC MIX

The accompanying illustration summarizes the difference in recurring costs for ground based vs the proposed GND/SOC mix. The recurring costs include the STS transportation costs to LEO as a function of the cargo delivered to LEO for each flight, the cost for additional STS days in orbit over and above the one day which is included in the transportation costs, and the labor turnaround costs. The Users Reimbursement Guide and the ground rules were used to establish the rates for the various activities. The greatest driver in establishing the SOC to GND differential was STS transportation costs for the various configurations.

As indicated, the proposed mix affords a saving of approximately $2M, $8M and $16M for the OTV, short duration MOTV and S-1 type mission, respectively. Incorporation of a pressurized hangar would increase each of these savings by another $1M per flight. If we consider the 1995 to 1996 time period as illustrating a typical or average operational traffic pattern a yearly savings of approximately $30M would be saved with the proposed mix. If the SOC included a pressurized hangar, a yearly saving of $36M for operations could be realized. An increase in the number of manned flights would increase the savings significantly.

COMPARISON OF TOTAL MISSION TURNAROUND COSTS WITHOUT SOC BASE



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MOTV TURNAROUND ANALYSIS

BACKGROUND
DATA

SOC/GND
TURNAROUND ANALYSIS

RECOMMENDED SOC/GND
MIX & SUPPORT REQMTS

CONCLUSIONS

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TURNAROUND CONCLUSIONS

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RECOMMENDED TURNAROUND MIX

- SPACE BASING MOTV AT SOC WITH PERIODIC RETURN TO GROUND FOR LABOR INTENSIVE TASKS (MAJOR OVERHAUL) RESULTS IN MINIMUM RECURRING COSTS
  - REDUCES STS TRANSPORTATION COSTS BY APPROX $30M PER YEAR (TRAFFIC MODEL SENSITIVE)
  - DECOUPLES STS & MOTV TURNAROUND
- PRESSURIZED HANGAR AT SOC REDUCES LABOR COSTS BY APPROXIMATELY 50%

TURNAROUND ANALYSIS RECOMMENDATION

The accompanying illustration contains the prime recommendations based on the results of the turnaround analysis discussed in the previous illustrations, and is self-explanatory.

TURNAROUND ANALYSIS RECOMMENDATIONS

- **SOC/GND TURNAROUND SCENARIO**

  SOC USED FOR OTV/MOTV FLIGHTS WITH MINIMUM MAINTENANCE
  - CONFIGURE FOR MISSION, SERVICE & GO
  - CONFIGURE FOR MISSION, PERIODIC MAINT., SERVICE & GO

  GND USED FOR
  - OVERHAUL OF OTV/MOTV APPROXIMATELY EVERY 8TH FLT
  - FOR CONTINGENCIES

- **SOC FACILITIES**
  - CAPABLE OF MATING, DEMATING, REFUELING, LRU REPLACEMENT, & SERVICING, LOGISTICS SUPPORT

- **OTV/MOTV**
  - ALL LRUs SOC ACCESSIBLE & REPLACEABLE
  - OPERATIONAL FLIGHT INSTRUMENTATION (OFI) CAPABLE OF HEALTH & STATUS CHECKS, IDENTIFICATION OF NON OPERATIONAL LRU & OVERALL SYSTEMS TESTS

- **GND**
  - MOTV PROCESSING FACILITY MOTV PF CAPABLE OF COMPLETE OVERHAUL & PERFORMANCE TESTS
  - MOTV PF CAPABLE OF PROCESSING CREW MODULE IN HORIZONTAL POSITION & CORE PROP. MODULE IN VERTICAL POSITION
  - VERTICAL PROCESSING FACILITY (VPF) USED TO MATE CREW & CORE MODULES FOR MOTV FLIGHTS

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ADDITIONAL TURNAROUND ISSUES

The accompanying illustration lists significant issues which require further study. The hardware and software definition to support the recommended SOC/ground turnaround is required. This should include further trades on the use of a pressurized hangar at SOC, whether horizontal or vertical processing of the OTV/MOTV is more cost effective and the use of removable RCS fuel tanks.

The definition of abort equipment required at SOC or a ground emergency landing field should also be defined.

MOTV

ADDITIONAL TURNAROUND ISSUES

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- DEFINE THE SPECIFIC EQUIPMENT AND FACILITIES REQ'D TO IMPLEMENT THE RECOMMENDED SOC/GND TURNAROUND MIX, SPECIFICALLY

	SOC	GND
– MATE/DEMATE	✓	✓
– REFUEL & SERVICE	✓	✓
– COMPLETE OVERHAUL		✓
– NOMINAL MAINTENANCE	✓	✓
– SOFTWARE	✓	✓

- DEFINE IMPACT ON OTV/MOTV DESIGN FOR SOC OPERATIONS

  – OTV SUBSYSTEMS
  – CREW MODULE SUBSYSTEMS
  – OPERATIONAL FLIGHT INSTRUMENTATION
  – SOFTWARE

- DEFINE EQUIPMENT REQ'D @ EMERGENCY LANDING SITE FOR OTV/ MOTV

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INTRODUCTION

OPERATIONAL REQMTS ANAL. & DEFINITION

MOTV CONCEPTS SUMMARY EVALUATION

CONCLUSIONS & RECOMMENDATIONS

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CREW CAPSULE/MISSION MODE OPTIONS

At the beginning of the main study, 19 generic missions were identified. During the course of that study, vehicle requirements were defined and analyzed. They can now be grouped into two categories. The 'common vehicle' category refers to a vehicle comprising a common crew capsule, a standard propulsion core and standard drop tanks whose number varies with the mission. Dedicated equipments are added, as required, for each mission. A second category requires dedicated vehicles to the extent that the crew capsule varies in size, interior configuration and crew number with each mission. The propulsion core and drop tanks are standard.

We are concerned with the 'common vehicle' category which has 15 of the 19 generic missions, including the five Design Reference Missions (DRMs) selected for the study extension.

Options considered for the crew capsule and mission mode evaluations are shown in the matrix. Considering mission modes, the four modes identified are those remaining from a previous study. An AMOTV 'lifting body' concept was eliminated in Phase 2 of the study when NASA indicated a preference for the 'aeroballute' (ABOTV) and 'lifting brake' (LBOTV) versions of an AMOTV, and directed us to include them as options.

Of the crew capsules considered over the course of the study, four types remain. They cover two-man crews and three-man crews, and they cover a comfort level varying from 'basic', where each crewman has private quarters, to 'functional minimum' which combines work station with private quarters. With mission modes APOTV, ABOTV and LBOTV, a common crew capsule, which is returned to Earth by shuttle, will satisfy all three modes.

AMRV, however, demands a crew capsule capable of direct entry to Earth from GEO.

CREW CAPSULES/MISSION MODE OPTIONS

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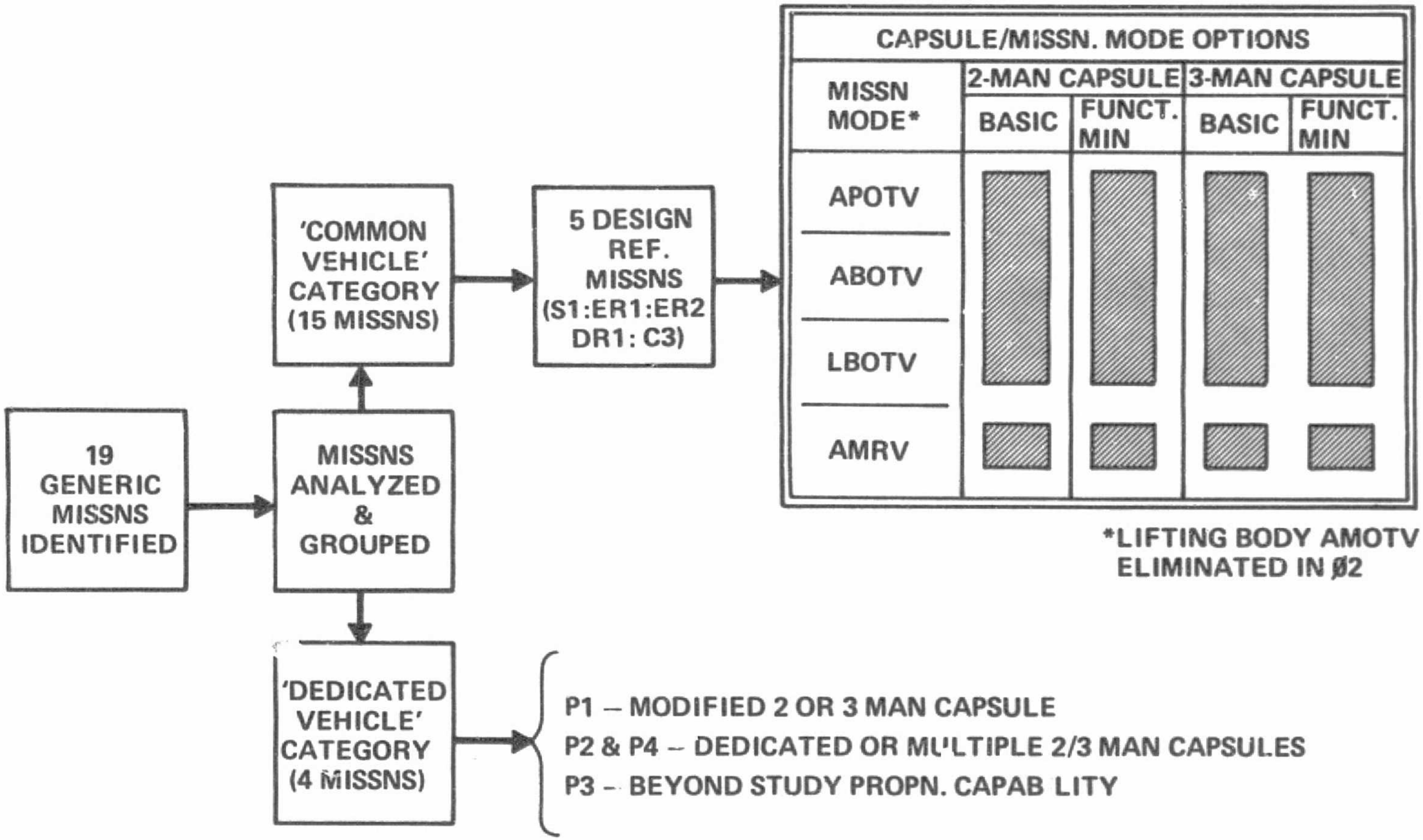

MOTV CONCEPT EVALUATION LOGIC FLOW

The objective of this evaluation is to identify a crew capsule and mission mode combination which best performs the five DRMs. Two types of capsule are considered, a 'non-entry' type which must be returned to earth by the shuttle and a 're-entry' type which can return directly. The 'non-entry' type is evaluated by first defining the number of men necessary to perform the mission tasks and then to see whether that crew number can cope with emergency or contingency EVA. Optional levels of comfort for the crew are then evaluated using criteria of costs, mission success and growth potential. The preferred capsule then becomes the baseline crew capsule for the APOTV, ABOTV, and LBOTV mission modes.

A 're-entry' type capsule is then defined to house the same number of crew and provide the same facilities as the selected 'non-entry' type.

Now the mission mode trade is made for APOTV vs. ABOTV vs. LBOTV vs. AMRV. These are evaluated to provide the baseline concept for mission mode and crew capsule. Criteria will fall under the headings of:

- Cost
- Performance
- Safety
- Mission Success
- Evolution
- Technology development
- Utility
- Debris

The impact of emergency return is considered as a side issue. If the baseline concept is APOTV, ABOTV or LBOTV, then, even in an emergency, the crew returns to LEO for rendezvous with a shuttle. Alternatively, a lifeboat can be added to the capsule for direct return of the crew. The third alternative is an AMRV in which the crew can always return directly to Earth. We consider these alternates in terms of safety, time to return and costs. If the baseline mission mode evaluation results in the AMRV being the selection then, of course, this emergency return investigation is unnecessary.

MOTV CONCEPT EVALUATION LOGIC FLOW

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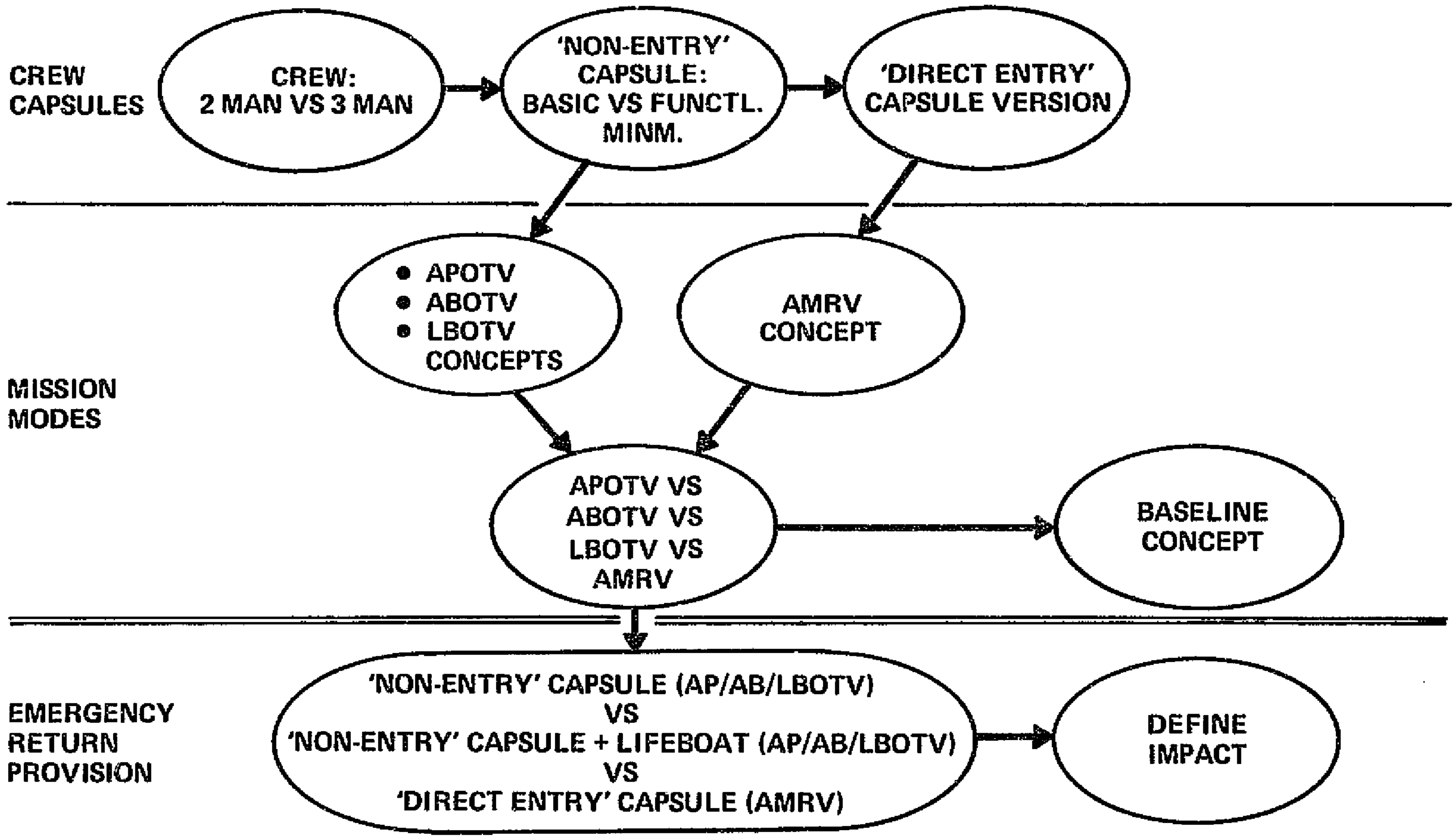
- GROUND BASED
- 5 DRMs



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TWO-MAN VS THREE-MAN CREW

The five DRMs were used for this evaluation. Criteria used considered the minimum crew necessary to perform mission tasks and whether that crew number could cope with emergency or contingency EVA.

Original manpower requirements, conducted in Phase I of the study, found that two men could perform four out of the five DRMs. The fifth DRM, C3, called for three men since some observation of the work-piece is necessary during final checkout. It was felt that a third man would be useful for this. On re-examination, two men could perform the mission at a penalty of 2.5% (55 min.) added to the 'on orbit' mission time. This seems acceptable.

EVA is either on a contingency basis, whereby the mission cannot be completed because some unforeseen circumstance cannot be handled by the IVA prime mode, or it is an emergency affecting safety of crew or vehicle. In either event, it is a 'failure mode' and our judgment is that both crewmen would go EVA, using the buddy system, to rectify the problem. Communication with the ground can be maintained via the vehicle. An alternative is for one man to go EVA while the other remains in the capsule, but he is suited, ready to go to the assistance of his mate if needed.

2-MAN VS 3-MAN CREW

DRMs = S1:ER1:ER2:DR1:C3

CRITERIA	2-MAN CREW	3-MAN CREW	JUDGMENT
• MISSION PERFORMANCE			
– 'MAIN STUDY' CREW REQUTS	S1:ER1:ER2:DR1	C3	
– WITH 2-MAN CREW	C3 ACCOMMODATED WITH 55 MIN PENALTY		ACCEPTABLE
• CONTINGENCY/ EMERGENCY EVA PERFORMANCE	• 1 EVA + 1 IN CAPSULE • 2 EVA + UNTEND. CAPSULE √	• 2 EVA + 1 IN CAPSULE	√ BECAUSE • FAILURE MODE • BUDDY SYSTEM • GROUND COMM. VIA MOTV

2 MEN CAN PERFORM DRMs WITHOUT SIGNIFICANT PENALTY

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TWO-MAN 'BASIC' CREW CAPSULE

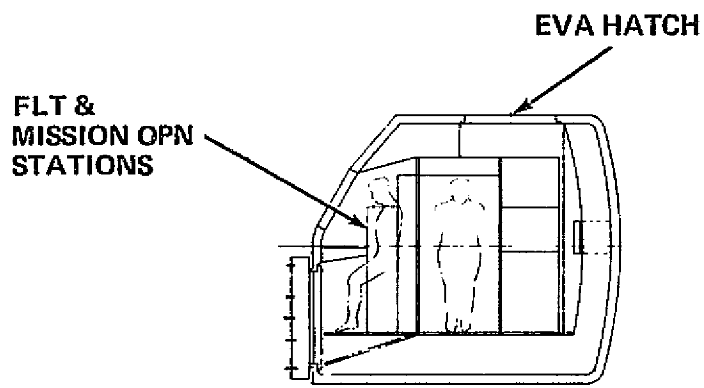
The following requirements were imposed on crew capsule concepts evolved during the main study and they are catered to in this 'basic' two-man capsule:

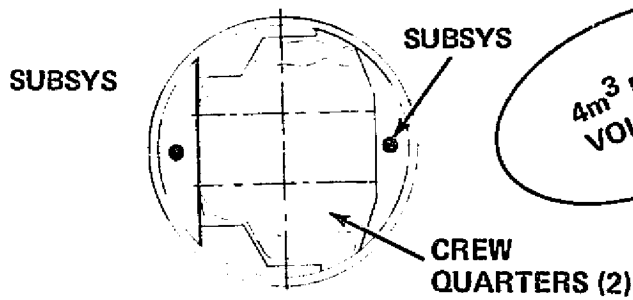
- Privacy for mixed crew bodily functions
- Individual quarters for privacy
- EVA suit donning volume and storage
- Waste management system
- Personal hygiene system
- Galley.

The capsule has two main functional areas. The flight and misssion station is located forward and has two operators, side by side, with their necessary controls. The aft section provides private crew quarters, each of which can be closed off by curtains, a galley and food storage, and a waste management facility. EVA suits are also stored and donned in this area. The aft wall of the capsule is lined with subsystems, which are also located under the floor. A personal hygiene facility is in the rear bank of subsystems.

Free volume per man is about $4m^3$, which provides Celentano 'performance' level of comfort for the longest generic mission (S2:27 days).

2-MAN 'BASIC' CREW CAPSULE





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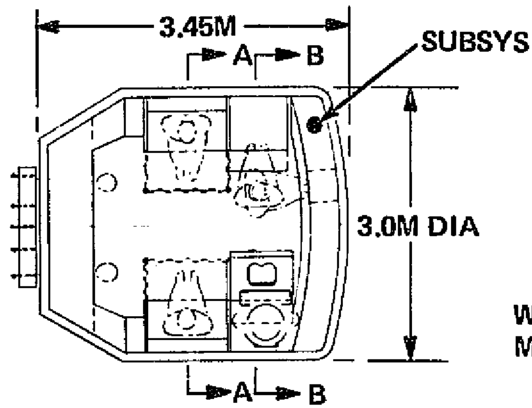

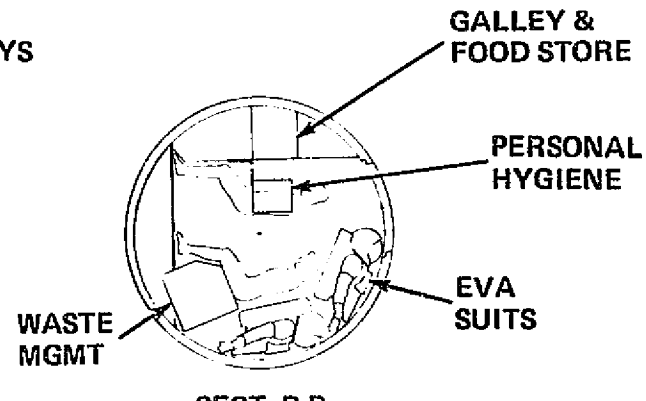

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2-MAN 'BASIC' CREW CAPSULE: RELATED WEIGHTS

For each of the five DRMs, this illustration gives preliminary weights for the 'basic' crew capsule and its associated subsystems carried in the propulsion core. These weights, plus the general purpose and dedicated mission equipments defined in the Mission Handbook, are the OTV payload for each mission.

Throughout the main study and this extension, a contingency of 25% has been added to capsule weights, and 15% to the propulsion module weights.

2-MAN 'BASIC' CREW CAPSULE: RELATED WEIGHTS (KG)

	S1	ER1/2	DR1	C3
• CREW CAPSULE				
STRUCTURE	1,274	1,274	1,274	1,274
THERMAL PROTECTION	39	39	39	39
EPS DISTRIBUTION	37	37	37	37
AVIONICS: COMMAND & DISPLAY	125	125	125	125
ECLS	298	298	298	298
CREW ACCOMMODATIONS	664	664	664	664
PROPULSION CONTROL	6	6	6	6
CONTINGENCY (25%)	611	611	611	611
TOTAL DRY WEIGHT	3,054	3,054	3,054	3,054
CREW (2)	163	163	163	163
CONSUMABLES	255	114	161	133
BURNOUT WEIGHT	3,472	3,331	3,378	3,350
• PROPN CORE: CAPSULE ASSOCIATED SUBSYS				
FUEL CELLS/TANKS/LINES	404	341	341	341
SOLAR ARRAY	193	-	-	-
CONVERSION/DISTRIBUTION	120	40	40	40
AVIONICS	30	30	30	30
RADIATOR FOR FUEL CELL Δ	8	8	8	8
CONTINGENCY (15% OF ABOVE)	113	63	63	63
FUEL CELL REACTANTS	370	175	323	244
TOTAL CAPSULE & RELATED WEIGHT	4,710	3,988	4,183	4,076

NOTE: EXCLUDES MANIPULATORS, ETC.: CHARGED TO GENERAL PURPOSE MISSION EQUIPMENT

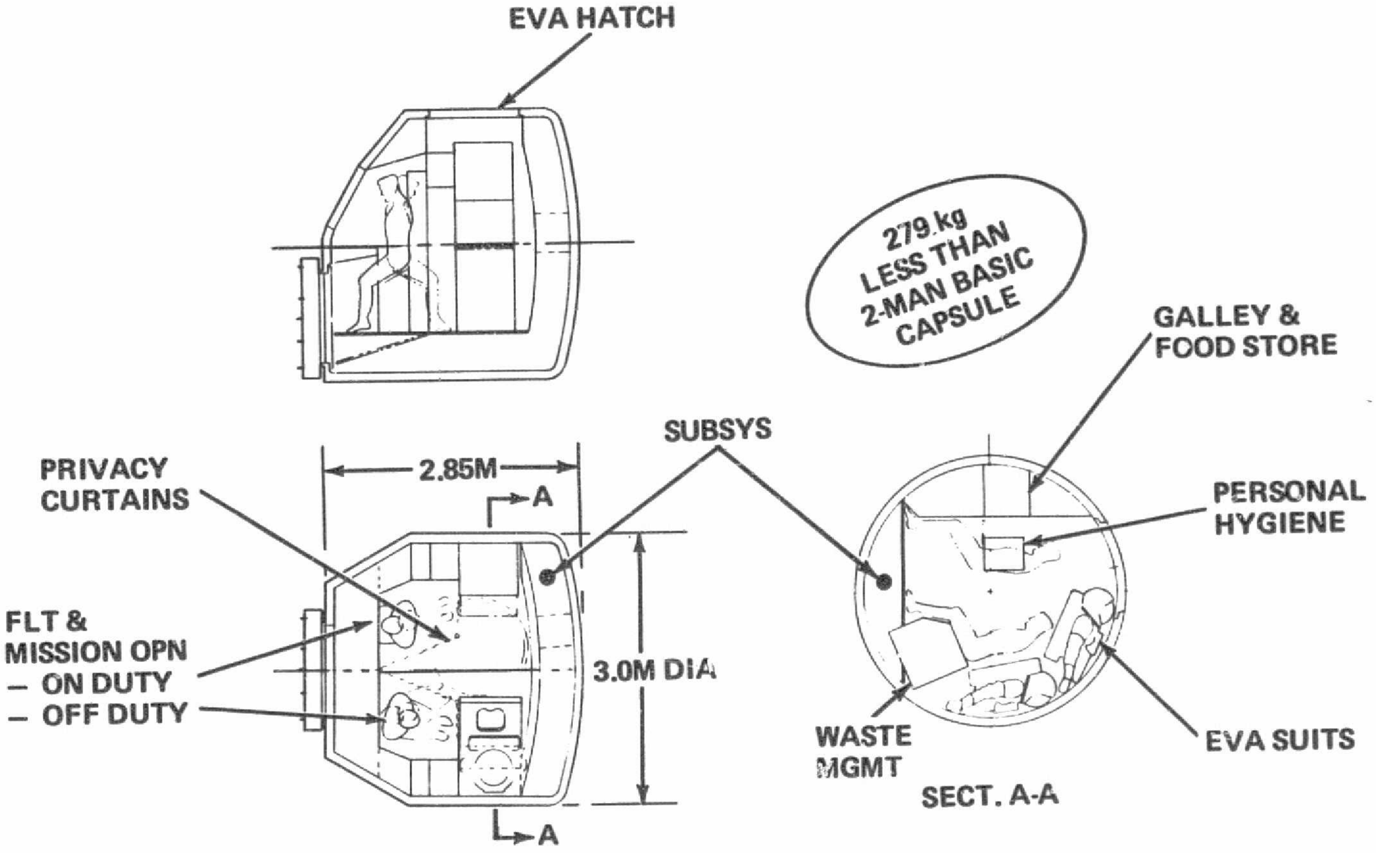
TWO-MAN 'FUNCTIONAL MINIMUM' CREW CAPSULE

The 'basic' crew capsule provided $4m^3$ of free volume for each crew member. This matched the Celentano "performance" curve for a 27-day mission duration. Most missions, including the DRMs, are much shorter and led to consideration of reducing this capsule volume without materially degrading the crew comfort level. The result is a 'Functional Minimum' capsule which is considered to be about minimum to provide the required facilities, store necessary subsystems, have sufficient free volume for crew movements and permit donning an EVA suit. Free volume is now about $3m^3$ per person.

This chart shows the capsule arrangement. It is 0.6m shorter than the 'basic', thus saving structure, TPS and lines runs which, together with crew accommodations, saves 279 kg. In arriving at this configuration, a requirement governing the 'basic' configuration was eased by combining work stations and private quarters. Now, privacy is obtained by the crew member pivotting in his seat for about 180° from his work position; he can then pull curtains around his territory. The flight/mission operation compartment and its subsystems stowage is unchanged from the 'basic' capsule. The aft section, catering for crew services and subsystems stowage, remains the same except that the bank of subsystems located inside the rear dome has been increased in depth to allow for essential stowage volume lost by shortening the capsule.

2-MAN "FUNCTIONAL MINIMUM" CREW CAPSULE

GRUMMAN



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2-MAN FUNCTIONAL MIN. CREW CAPSULE

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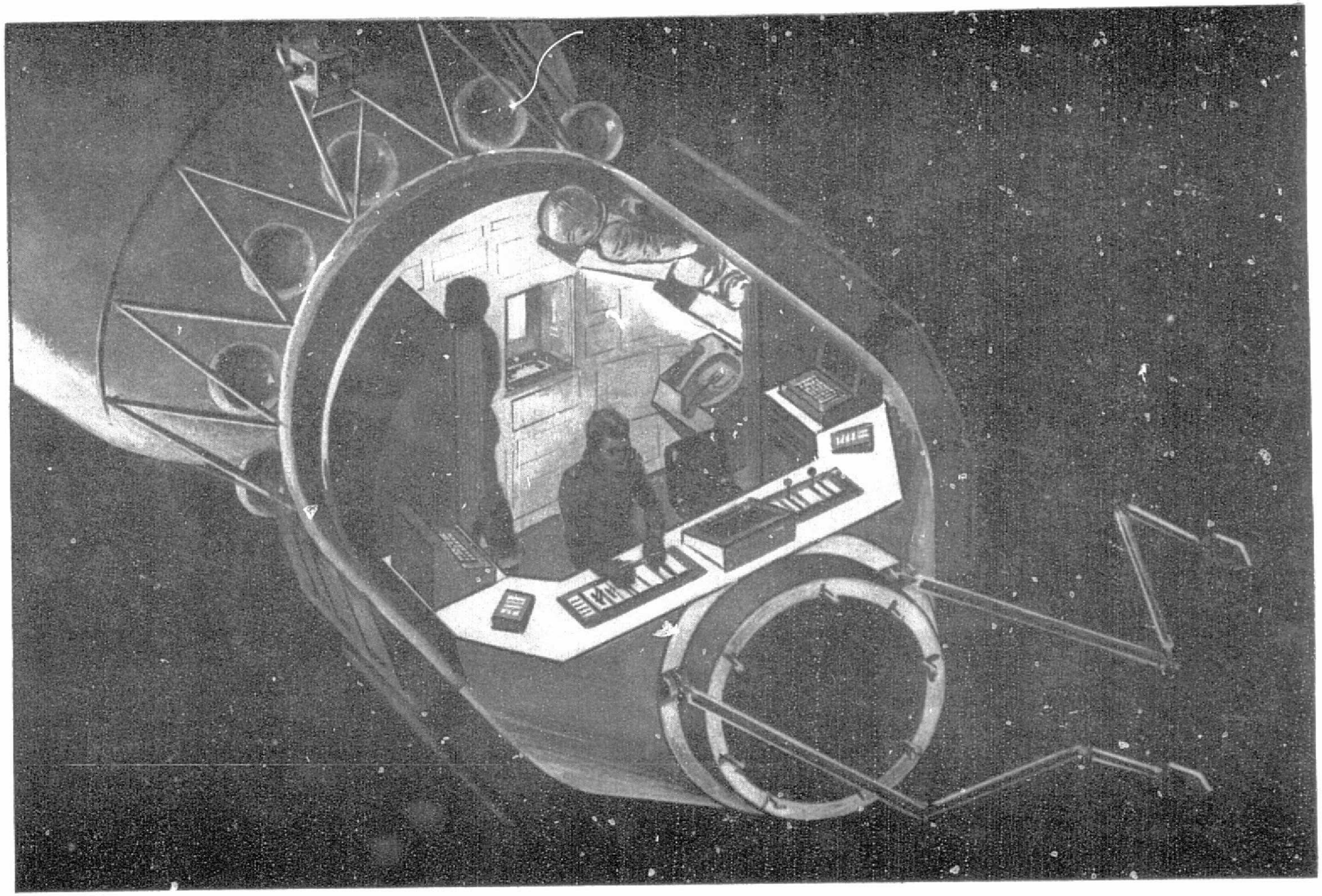

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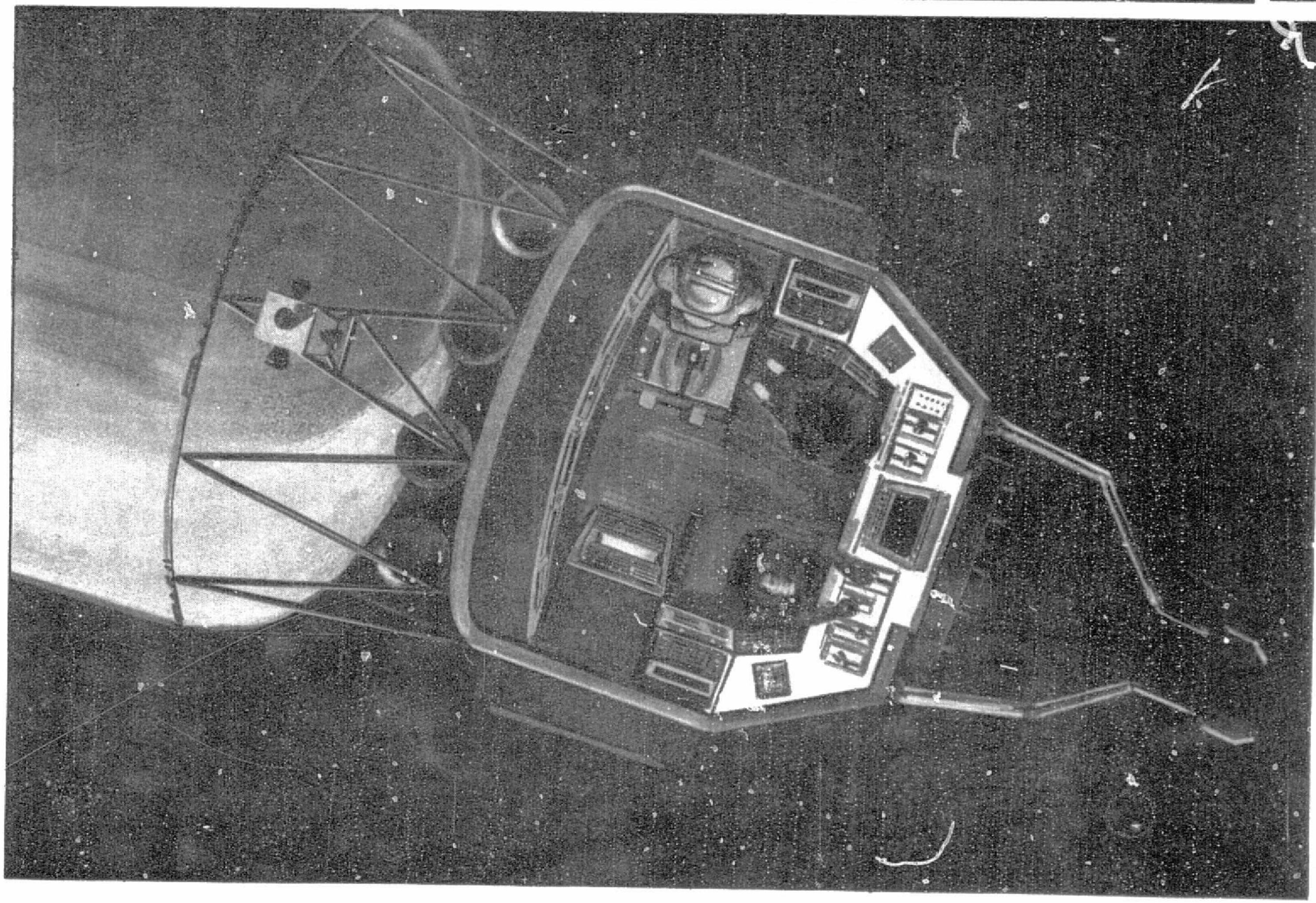
FUNCTIONAL MIN. CREW CAPSULE



2-MAN 'FUNCTIONAL MINIMUM' CREW CAPSULE: RELATED WEIGHTS

As with the earlier illustration for the 2-man 'basic' capsule weight, this illustration give weights for the capsule and associated subsystems carried in the propulsion core. It is a smaller capsule and, therefore, lighter structure, TPS, etc. Crew accommodations are more spartan in this capsule than the 'basic'.

Capsule associated subsystems are the same weights as for the 'basic' capsule.

2-MAN 'FUNCTIONAL MINIMUM' CREW CAPSULE: RELATED WEIGHTS (KG)

GRUMMAN

	S1	ER1/2	DR1	C3
• CREW CAPSULE				
STRUCTURE	1,113	1,113	1,113	1,113
THERMAL PROTECTION	33	33	33	33
EPS DISTRIBUTION	37	37	37	37
AVIONICS: COMMAND & DISPLAY	125	125	125	125
ECLS	296	296	296	296
CREW ACCOMMODATIONS	610	610	610	610
PROPULSION CONTROL	6	6	6	6
CONTINGENCY (25%)	555	555	555	555
TOTAL DRY WEIGHT	2,775	2,775	2,775	2,775
CREW (2)	163	163	163	163
CONSUMABLES	255	114	161	133
BURNOUT WEIGHT	3,193	3,052	3,099	3,071
• PROPN CORE: CAPSULE ASSOCIATED SUBSYS				
FUEL CELLS/TANKS/LINES	404	341	341	341
SOLAR ARRAY	193	-	-	-
CONVERSION/DISTRIBUTION	120	40	40	40
AVIONICS	30	30	30	30
RADIATOR FOR FUEL CELL Δ	8	8	8	8
CONTINGENCY (15% OF ABOVE)	113	63	63	63
FUEL CELL REACTANTS	370	175	323	244
TOTAL CAPSULE & RELATED WEIGHT	4,431	3,709	3,904	3,797

NOTE: EXCLUDES MANIPULATORS, ETC.: CHARGED TO GENERAL PURPOSE MISSION EQUIPMENT

CREW CAPSULE WEIGHT COMPARISON

LM ASCENT STAGE VS 2-MAN MOTV FUNCTIONAL MIN.

A preceding illustration discusses free volume per man vs. mission duration for various levels of comfort. That illustration shows, as a comparison with our candidate capsules, data points for Apollo CM, LM and for Gemini cabins. A further comparison is illustrated here for LM ascent stage weight vs. that of the MOTV 2-man functional minimum capsule.

Although both vehicles house 2 men for 3 days, they vary widely in technology (1965 vs. 1980), in shape (multifaceted vs. cylinder), in level of radiation protection, and in load paths. Each of these differences favors one or the other vehicles and it is not, strictly, an "apples to apples" comparison. However, it serves to show that MOTV crew capsule weights are within the ball park.

LM structure weight is factored up by the ratio of the pressurized volumes to give an equivalent weight. The other weights are not greatly influenced by the vehicle size. Comparing inert weights, they are within 7.5% when contingencies are allowed for in the MOTV weights.

CREW CAPSULE WEIGHT COMPARISON: LM ASCENT STAGE VS 2-MAN MOTV FUNCTIONAL MIN.

MOTV

GRUMMAN

- 2-MAN, 3-DAY MISSION
- LM 12 ASCENT STAGE, ACTUAL WEIGHTS USED
  - PROPULSION & REACTION CONTROL DELETED
- SUBSYS TECHNOLOGY LEVELS DIFFER
- VEHICLE SHAPES DIFFER
  - LM HAS EXTRANEOUS STRUCTURES
- MOTV SHELL DESIGNED FOR RADIATION PROTECTION (1.1 cm AL. EQUIV)
- THRUST STRUCTURE & LOAD PATHS DIFFER
- WEIGHT COMPARISON (Kg)

LM A/S		MOTV	Δ
– STRUCTURE: 628 X PRESS.VOL RATIO (2.5)	= 1571	1391	
– REMAINDER	= 1140	1522	
– INERT WT	2711	2913	+7.5%

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MOTV TWO-MAN CREW CAPSULE SENSITIVITY: STRUCTURE WT & FREE VOL/MAN VS MISSION DURATION

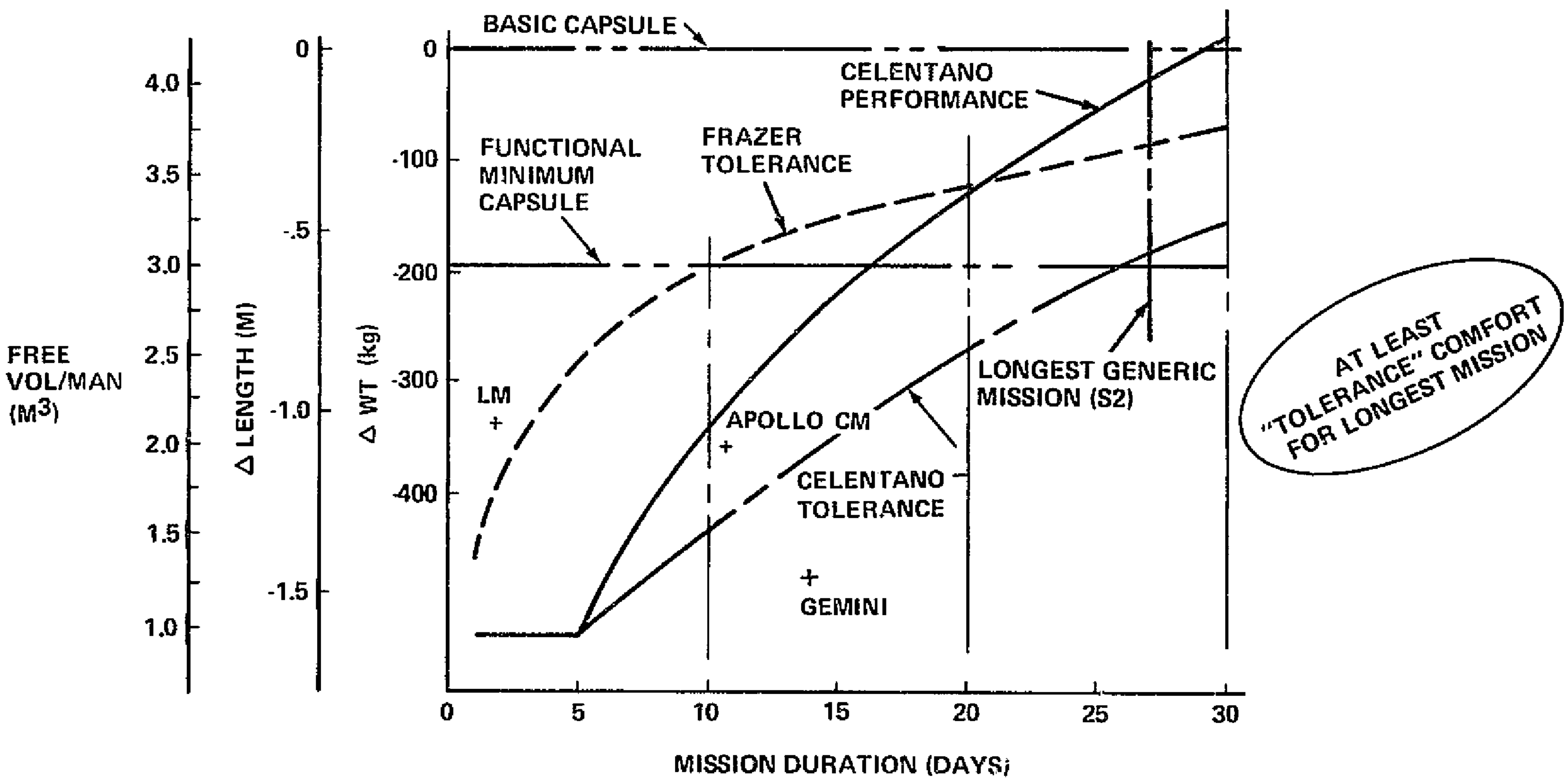
The amount of free volume per man that should be provided in the MOTV crew capsule remains subjective. In the main study, we made several recommendations for living volume in prolonged space missions. Here, we have focused on three recommended curves, namely: Celentano Performance; Celantano Tolerance and Frazer Tolerance.

This illustration shows capsule weight and length sensitivity to changes in mission duration and free volume per man criteria as a function of crew comfort level. The 'basic' two-man capsule has just over $4m^3$ free volume per man and provides Celentano 'performance' level comfort for up to 29 days mission duration. The loss in free volume per man and the structure weight saved by reducing capsule length can be determined, together with the change in crew comfort level. The 'functional minimum' capsule is 0.6m shorter than the 'basic', which reduces free volume per man to $3m^3$ and saves about 190 kg of structure weight. Celentano 'performance' level comfort is now good for 16 days with this capsule, but the lower Celentano 'tolerance' comfort is good for 26 days.

MOTV 2-MAN CREW CAPSULE SENSITIVITY: STRUCTURE WT & FREE VOL/MAN vs MISSION DURATION

GRUMMAN

- RAD. PROTECTION EQUIV TO 1.1cm AL
- INCL 25% CONTINGENCY ON WEIGHTS



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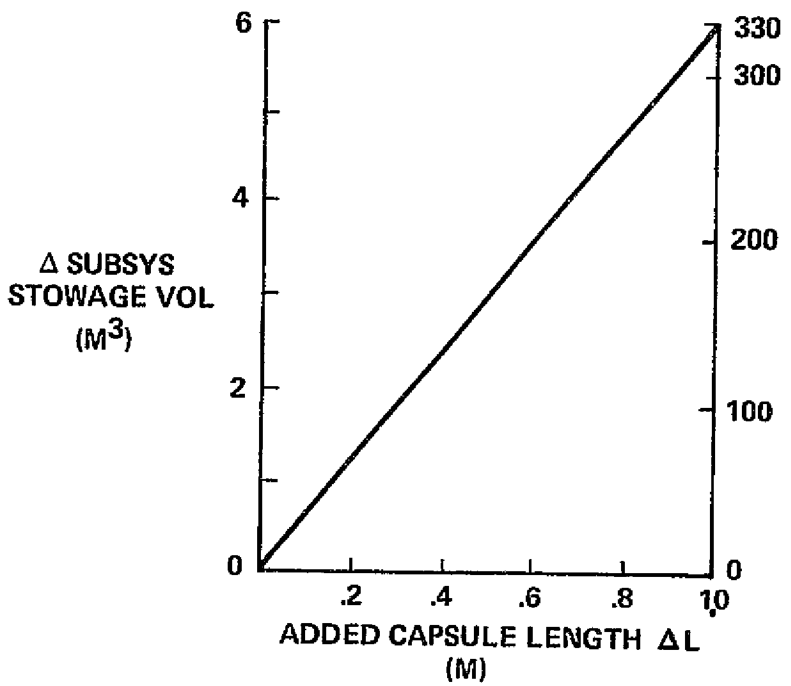
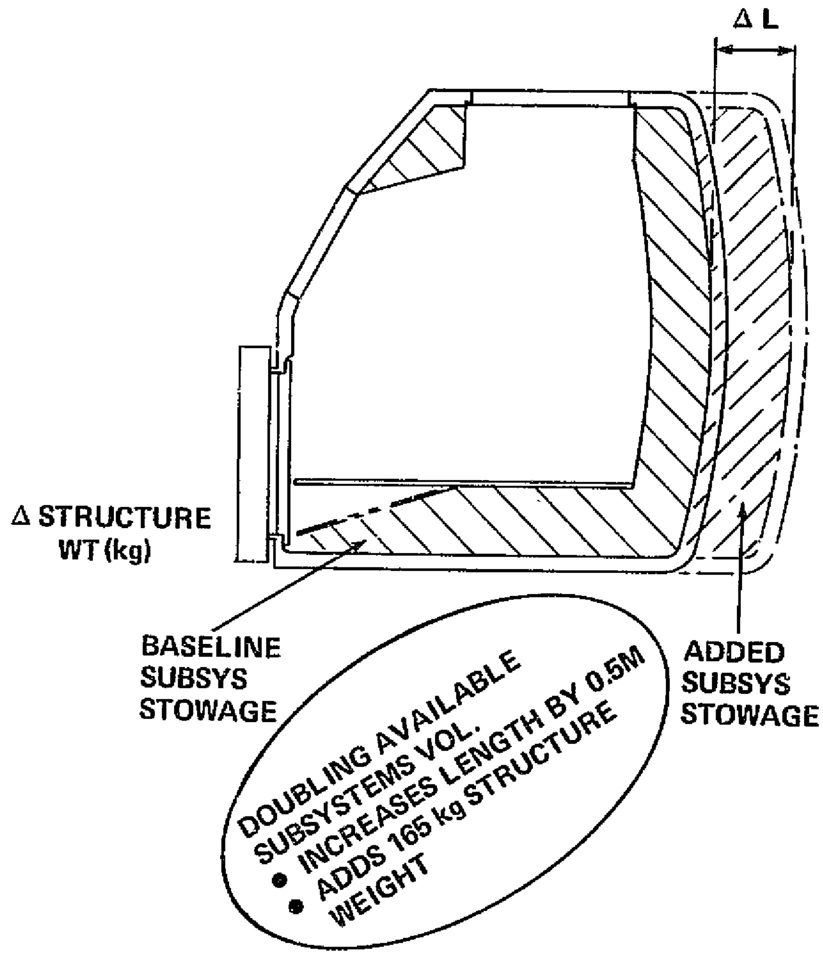
FUNCTIONAL MINIMUM CAPSULE - PENALTIES FOR PROVIDING ADDED SUBSYSTEM STOWAGE

Volume required for stowing the subsystems identified to date is approximately $3m^3$. The functional minimum capsule provides that volume with no margin for added requirements. This illustration shows the penalties for providing additional volume in the bank of subsystems located inside the aft dome. To double the existing available volume, by adding $3m^3$, means an additional 0.5m of capsule length and an increase of 165 kg in structure weight.

FUNCTIONAL MINIMUM CAPSULE – PENALTIES FOR PROVIDING ADDITIONAL SUBSYS STOWAGE





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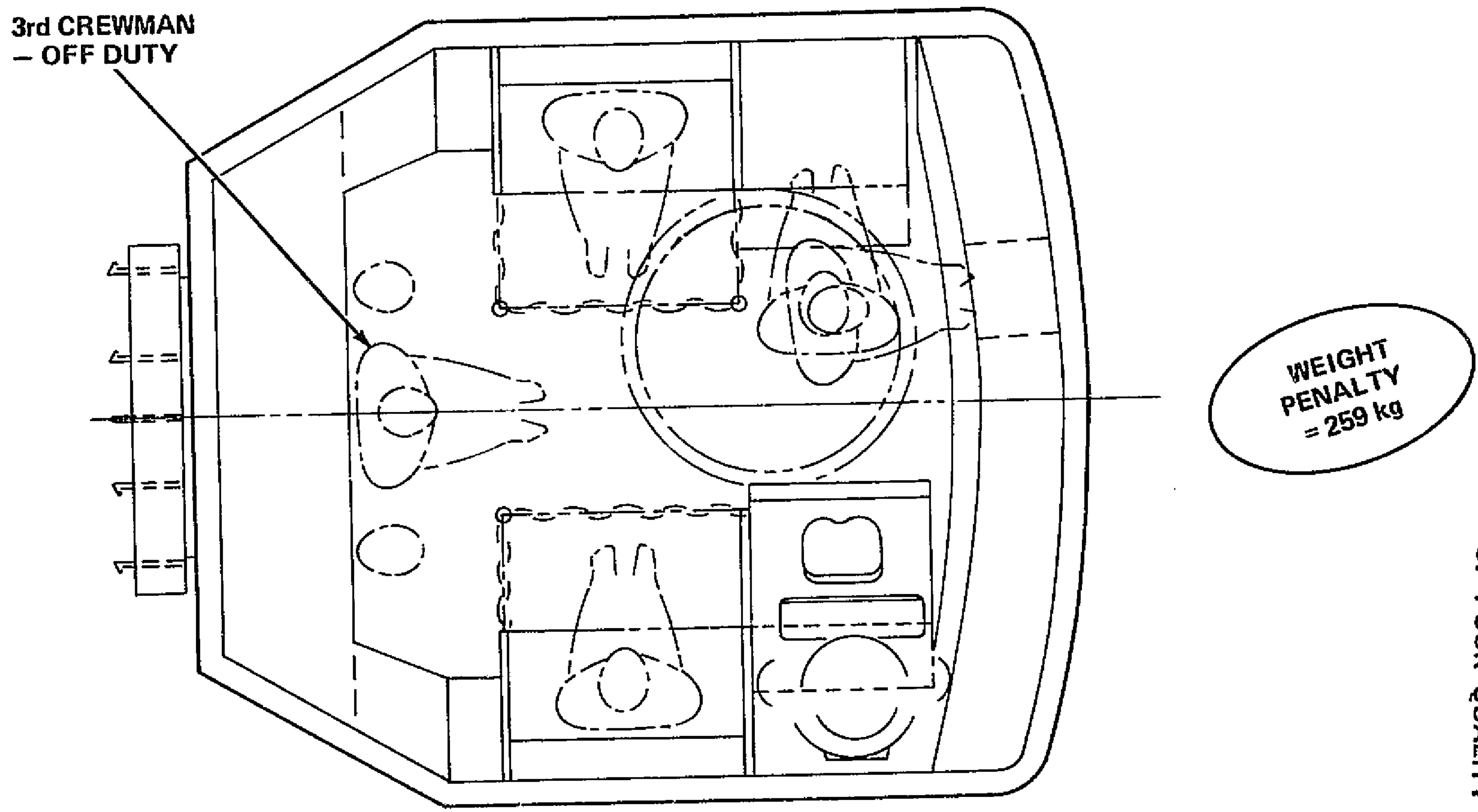
3 MEN OCCUPYING A 2-MAN 'BASIC' CAPSULE

Analysis of the DRM scenarios shows that two-man crews can perform all missions. However, it is possible that a particular mission may require a third crewman, perhaps to supply special expertise. The layout shown takes the two-man 'basic' capsule and shows that a third man can be accommodated, off duty, in the flight deck area. During the time when mission tasks are being performed, the two usual work positions on the flight deck will be occupied, with the third man either assisting as required, or resting/working in one of the two permanent rest positions.

The weight penalty for carrying the third man, his equipment and subsystems deltas is 259 kg.

3 MEN OCCUPYING A 2-MAN 'BASIC' CAPSULE



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CREW CAPSULE: 'BASIC' VS 'FUNCTIONAL MINIMUM' EVALUATION

Having selected two-man crew as baseline, the next trade defined in our concept evaluation logic flow is 'basic' vs 'functional minimum' capsule to house the crew. With just two options to evaluate, there is no points system ranking with which to be concerned. However, with this system of evaluation, some criteria are considered to be of more importance than others, particularly those affecting costs and safety. Usually, these are given twice the weight of other criteria. Hence, the DDT&E and cost per mission have been given a factor of 2. Production costs are not considered to have the same impact as the other two costs and are not weighted. Although cost differentials between the two capsules are small in this evaluation, they show the trend that 'functional minimum' will always be less costly than the 'basic capsule'. Therefore they remain as discriminators. Safety, the other high ranking criterion, was the same for both capsules and, consequently, was not included. Similarly, other criteria, such as flight and mission station utilization, was the same for both capsules and was excluded. Preceding illustrations give back-up for some of the evaluations.

Length of capsule is a factor because of its demand on shuttle cargo bay length. Weight is reflected in cost figures, but is a limitation on orbiter cargo manifest. Crew comfort level gives the days which each capsule can accommodate the crew at various levels of habitability, as shown on a preceding illustration. Since 'functional minimum' can support the crew at the higher Celantano 'performance' level for four of the five DRMs with a slight descent into the 'tolerance' level zone for the fifth DRM, it is the selection for this parameter. Subsystems stowage in 'functional minimum' is preferred, since it is just adequate with no excess, but a preceding illustration gives the penalties for providing added subsystems volume. Area for EVA preparation is adequate in the 'functional minimum' and is therefore preferred.

The 'basic' capsule wins out in the area of direct mounting of external mission equipment to rail supports on the capsule shell. It can also accommodate an extra man or mount a work bench, at some inconvenience.

'Functional minimum' is the winner of this straight scoring system and becomes the preferred capsule since it provides adequate performance at lower costs and is less in weight and length.

MOTV

CREW CAPSULE: 'BASIC' VS 'FUNCTIONAL MINIMUM' EVALUATION

GRUMMAN

- 2 MAN CREW
- DRM/DURATION (DAYS) S1/19:ER1/4:ER2/4:DR1/9:C3/6

CRITERIA	WTG. FACTOR	BASIC CAPSULE	SCORE	FUNCTL. MIN CAPSULE	SCORE
• LENGTH	1	3.45 M		2.85 M √	1
• WEIGHT- DRY	1	3079 Kg		2800 Kg √	1
• UTILITY					
– CREW COMFORT LEVEL					
• DAYS AT CELENTANO 'PERFORMANCE'	1	29		16 √	1
• DAYS AT CELENTANO 'TOLERANCE'		>50		26	
– SUBSYS. STOWAGE VOL EXCESS	1	12.5%		ZERO √	1
– MISSN. EQUIPT DIRECT MOUNT	1	S1:ER1/2:DR1 √	1	ER1/2:DR1	
– EVA PREPN/EGRESS	1	COMFORTABLE		ADEQUATE √	1
• VERSATILITY					
– ADD 1 MAN OR 'IN CABIN' OPS	1	YES √	1	NO	
• COSTS					
– DDT&E	2	$309M		$302M √	2
– PRODN (2 SETS + SPARES)	1	$106M		$104M √	1
– CPM Δ (AVERAGE)	2			$0.8M LOWER √	2
			2	√	10

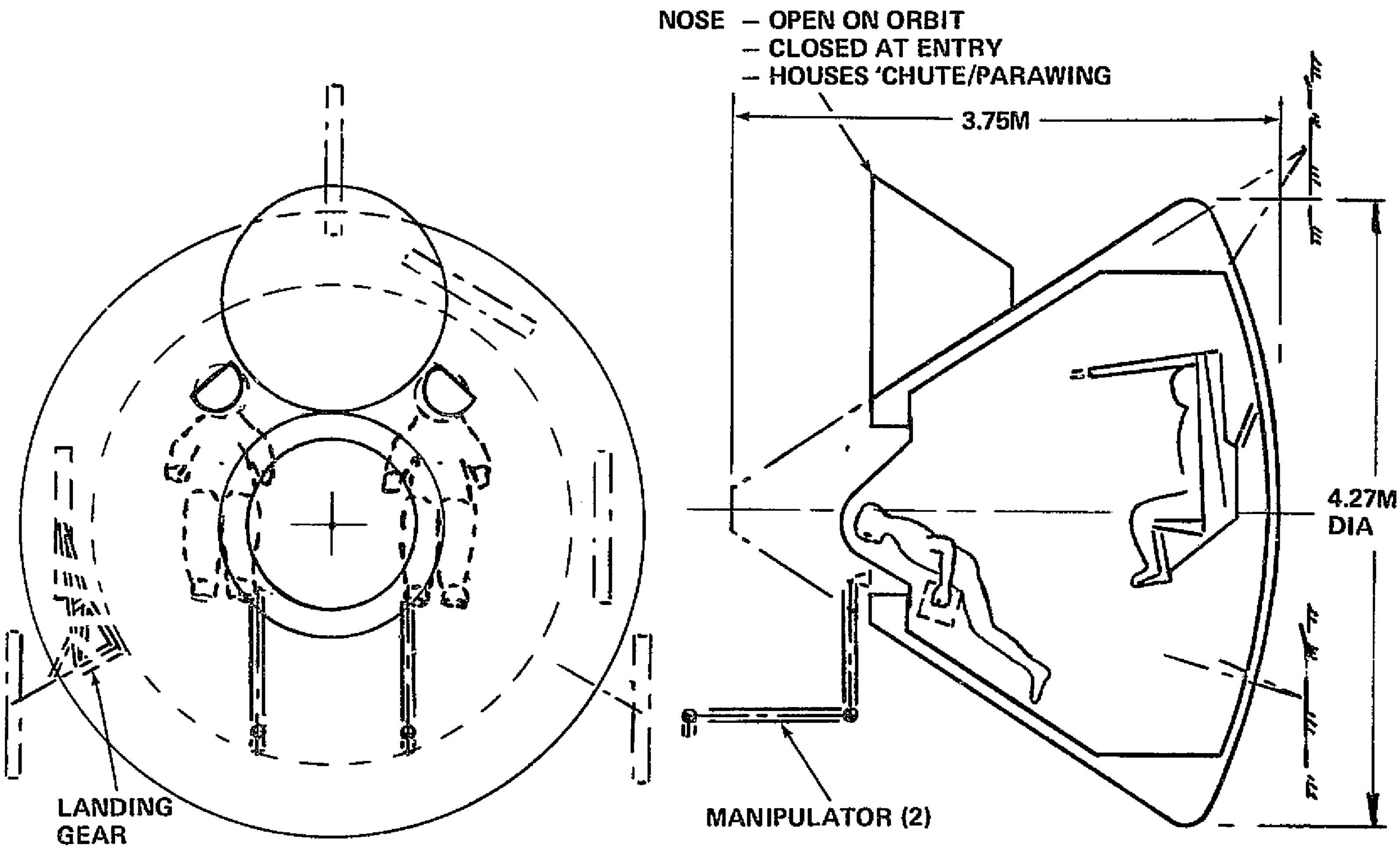
FUNCTL. MIN
–ADEQUATE PERFORMANCE
AT LEAST COST/WT/LENGTH

R80-1982-040P

TWO-MAN 'DIRECT ENTRY'CREW CAPSULE - FUNCTIONAL MINIMUM

The two-man 'functional minimum' capsule is now the baseline and its configuration as a capsule which is always returned to Earth in an orbiter, is shown on a preceding illustration. A 'direct entry' version of this capsule must be defined for the AMRV mission mode. This capsule is similar in size and shape to the CM used in the Apollo program. It provides facilities similar to the 'non-entry' capsule but, additionally, it has equipment for entry and landing. These include the capsule heatshield, deceleration SRM, parachutes/parawing, landing gear and the entry couches for the crew.

2-MAN 'DIRECT ENTRY' CREW CAPSULE – FUNCTIONAL MINIMUM



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TWO-MAN 'DIRECT ENTRY' CREW CAPSULE WEIGHT

This weight statement for the 'direct entry' crew capsule includes necessary entry and capsule recovery penalties. Re-entry TPS is 818 kg. A 4 kW-hr battery power supply is required for the time after separation from the propulsion core. Also required after separation are full GN&C and communications at 115 kg and full RCS at 94 kg. A 15% penalty is added to ECLS for heat sink provisions during re-entry, when the radiators are not functioning. High 'g' couches are added for the crew. Recovery items consist of chutes (164 kg), retro SRM (247 kg) and landing gear (88 kg).

A contingency factor of 25% is added to these dry weights.

MOTV

2-MAN 'DIRECT ENTRY' CREW CAPSULE WEGHT

GRUMMAN

CREW CAPSULE	WEIGHT (kg)
STRUCTURE	665
THERMAL PROTECTION	818
EPS	77
AVIONICS	255
ECLS	401
CREW ACCOMMODATION	704
RCS	94
RECOVERY (CHUTES:SRM:LAND. GEAR)	499
CONTINGENCY (25%)	878
TOTAL DRY WEIGHT	4,391

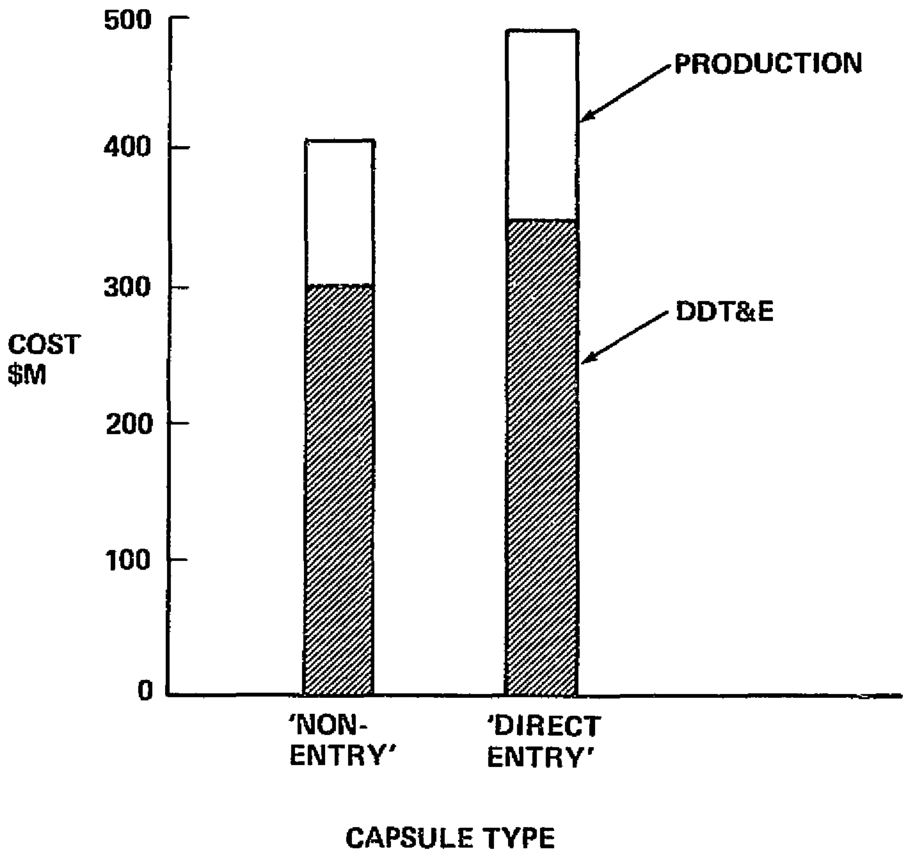
R80-1982-041P

CREW CAPSULE COSTS: 'NON-ENTRY' VS 'DIRECT ENTRY'

There are two capsules which, between them, satisfy the four candidate mission modes. APOTV, ABOTV and LBOTV use the 'non-entry' capsule, while AMRV requires a capsule capable of direct entry. DDT&E and production costs are given here for the two alternates. The higher costs for the direct entry capsule are mainly attributable to its entry and recovery requirements.

CREW CAPSULE COSTS: 'NON ENTRY' (AP/AB/LBOTV) VS 'DIRECT ENTRY' (AMRV) – 2-MAN 'FUNCTIONAL MINIMUM' CAPSULE

GRUMMAN



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TECHNOLOGY ISSUES: CREW CAPSULE RELATED

This illustration lists some of the crew capsule related technology issues requiring development.

EVA, with a two-man crew, may lead to both men being outside the capsule with 'voice' the only means of communication with the capsule. Development of voice synthesis and recognition is important for this eventuality. There is no airlock for EVA ingress and egress; therefore, the cabin atmosphere is dumped or pumped down, leading to vacuum within the cabin for perhaps a 6-hour period. Subsystems components, such as CRTs, capable of operating in continuous vacuum, should be developed.

Remotely operated manipulators are currently being developed by Grumman using the master/slave system. This has 'in-house' funding and has potential use in the MOTV and the MRWS programs. A Grumman-owned facility, called Large Amplitude Space Simulator (LASS), is being used in this simulation effort. Similarly, a stabilizer for anchoring a workpiece to an operation station is being developed in LASS for the MRWS program.

TECHNOLOGY ISSUES: CREW CAPSULE RELATED

- SUBSYSTEMS AUTONOMY
  - DEVELOP VOICE SYNTHESIS/VOICE RECOGNITION FOR COMMAND & CONTROL
  - DEVELOP COLOR CRTs CAPABLE OF OPERATING IN CONTINUOUS VACUUM
- REMOTELY OPERATED MANIPULATOR SYSTEM
  - MASTER/SLAVE SYSTEM CURRENTLY UNDER DEVEL (GRUMMAN 'IN HOUSE' FUNDS)
  - GRUMMAN LASS DEVEL FACILITY BEING USED FOR THIS EFFORT (MRWS & MOTV PROGRAMS)
- STABILIZER
  - CURRENTLY UNDER DEVEL FOR MRWS PROGRAM (NAS 9-15881)
  - LASS FACILITY BEING USED FOR THIS DEVEL

MOTV MISSION MODES TRADE GUIDELINES

Characteristics to be used in the mission modes evaluation are given in this illustration. The modes considered are APOTV, Grumman's all propulsive baseline, which uses propulsive thrust to decelerate: ABOTV (aerobraking) and LBOTV (lifting brake) which are vehicles using aerodynamic maneuvering to decelerate in the upper atmosphere, as proposed by the OTV concept study contractors: AMRV, an aero maneuvering vehicle whose crew return directly to Earth in a capsule similar to the Apollo CM.

ΔVs used in performance calculations are given for the vehicles, together with the engine I_{sp}. All vehicles were normalized to 1-1/2 stage disciplined concept using the same size propulsion core and drop tanks. The payload is considered to be picked up in the LEO; this divorces the issue of additional STS launches for the payload being influenced by its weight and size.

GUIDELINES FOR MOTV MISSION MODE TRADES

MOTV

GRUMMAN

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155, 156

MISSION MODES:	–	ALL PROPULSIVE (APOTV)		
	–	AERO ASSIST (ABOTV)		
		(LBOTV)		
	–	DIRECT ENTRY (AMRV)		
ΔV REQMTS:	–	TO GEO	= 14030 FPS	ALL MODES
	–	TO LEO	= 13816 FPS	APOTV
			= 6530 FPS	ABOTV & LBOTV
	–	GEO DEORBIT	= 8806 FPS	AMRV
	–	LEO CIRCULAR	= 7798 FPS	AMRV PROPN. CORE
ENGINE PERFORMANCE:	–	I_{sp} = 458 SEC (RL10 DER IIB)		
STAGE TYPE:	–	1½ STAGE DISCIPLINED		
RECOVERY MODES:	–	BY STS IN LEO (APOTV, ABOTV, LBOTV)		
	–	DIRECT ENTRY FOR AMRV CREW CAPSULE: PROPULSION MODULE RECOVERED BY STS IN LEO		
	–	RETURN TO SOC		
PAYLOAD:	–	PICKED UP IN LEO & DELIVERED TO GEO		

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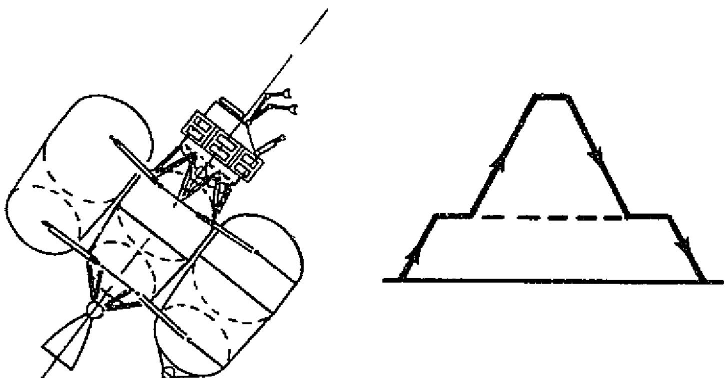
MISSION MODE OPTIONS

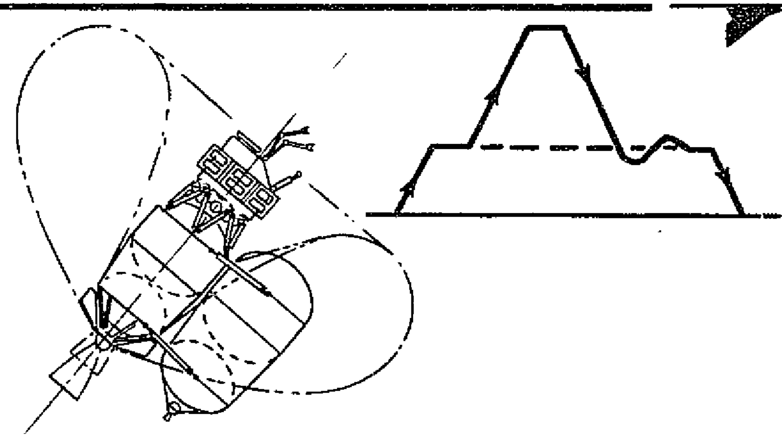
This illustration shows a sketch of the MOTV configuration for each of the four candidate mission modes. To reflect the change in number of drop tanks with mission mode, the configurations for ER1 mission at LEO ignition are shown. The ABOTV sketch shows, in phantom, the ballute used to decelerate the vehicle in the upper atmosphere at LEO on return from GEO. Similarly, LBOTV shows the lifting brake. Alongside each sketch, a diagramatic representation of the particular mission mode is shown. In all modes except AMRV, a loitering shuttle (dotted line) waits in LEO to bring the vehicle to Earth. With AMRV, the loitering shuttle returns only the propulsion core since the crew have returned directly to Earth in their capsule.

MISSION MODE OPTIONS – LEO IGNITION CONFIGURATION – MISSION ER1 (TYPICAL)

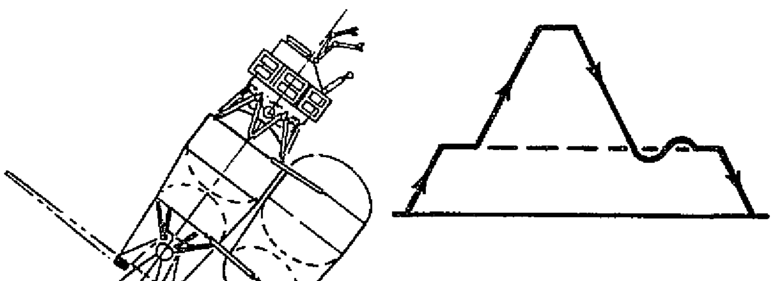
GRUMMAN



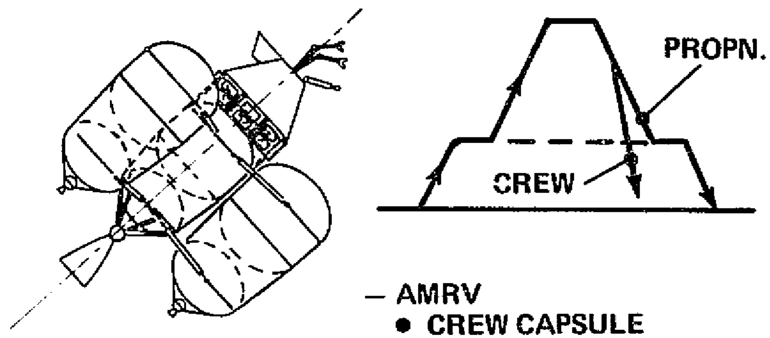
– APOTV
- CREW CAPSULE
- PROPN. CORE
- DROP TANK (2)



– ABOTV
- CREW CAPSULE
- PROPN. CORE
- DROP TANK (1)



– LBOTV
- CREW CAPSULE
- PROPN. CORE
- DROP TANK (1)



– AMRV
- CREW CAPSULE
- PROPN. CORE
- DROP TANK (3)

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MISSION MODE TRADE - CRITERIA CONSIDERED

This is a listing of the criteria considered in evaluating the four mission modes. Some of them, those marked 'secondary', were adjudged to be equal ranking among APOTV, ABOTV and LBOTV, essentially because they use the same crew capsule. AMRV, however, suffered by comparison for these 'secondary' criteria. It was decided, therefore, that an evaluation of the four modes would be made using only the criteria marked 'primary' as discriminators. If AMRV came out ahead, then the modes would be reevaluated using all the criteria listed here.

MISSION MODES TRADE – CRITERIA CONSIDERED

GRUMMAN

• PERFORMANCE	
– PAYLOAD DEPLOYED	P
– PAYLOAD ROUNDTRIP	P
• COSTS	
– DDT&E	P
– PRODUCTION	P
– COST PER MISSION	P
• SAFETY	
– SINGLE POINT FAILURE	P
– MISSION ABORT	S
• EVOLUTION	
– LEAST DEVEL START	P
– GROWTH POTENTIAL	P
• TECHN. DEVEL	
– MATERIALS	P
– SYS/SUBSYS	P
– RETURN FLT. MODE	P
• UTILITY	
– GRND TURNAROUND	P
– PAYLOAD DEPLOY MTG.	P
– PAYLOAD RETURN MTG.	S
– IVA PERFORMANCE	S
– EASE OF EVA EGRESS	S
– ACCESS TO MISSN HDWRE	S
• DEBRIS POTENTIALS	S

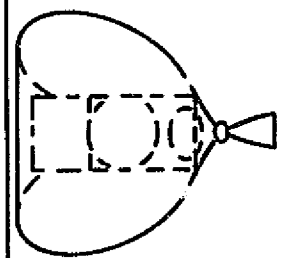
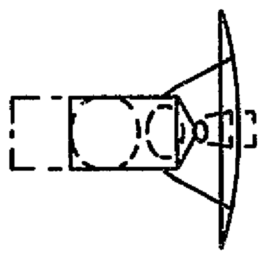
CODE: P = PRIMARY CRITERIA
S = SECONDARY CRITERIA

DEPLOYED AND ROUND TRIP PAYLOAD CAPABILITIES

This illustration summarizes the deploy and round trip payload capabilities of the four candidate flight modes, each using a propulsion core with 17,500 kg propellant capacity and an added drop tank at each subsequent STS launch. Each tank carries either 25,416 kg or 26,663 kg of propellant, depending upon other payload chargeable items carried by the shuttle.

DEPLOYED & ROUND TRIP PAYLOAD CAPABILITIES (1,000s kg)

GAC CORE DESIGN: W_P = 17,500 kg

NO OF STS LAUNCHES	APOTV		ABOTV		LIFTING BRAKE		AMRV	
								
	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$	$W_{PL\text{-}D}$	$W_{PL\text{-}RT}$
1	–	–	2.64	1.38	0.46	0.24	–	–
2	11.79	3.93	14.45	9.28	12.67	8.13	–	–
3	22.74	8.68	25.40	16.31	23.62	15.16	12.32	3.77
4	33.69	13.19	36.35	23.34	34.57	22.20	23.27	7.54
5	44.64	17.48	47.30	30.37	45.52	29.23	34.22	11.09

D:DEPLOYED RT:ROUND TRIP

ABOTV BEST DEPLOY & ROUND TRIP P.L. TO GEO

APOTV VS ABOTV VS LBOTV VS AMRV COSTS

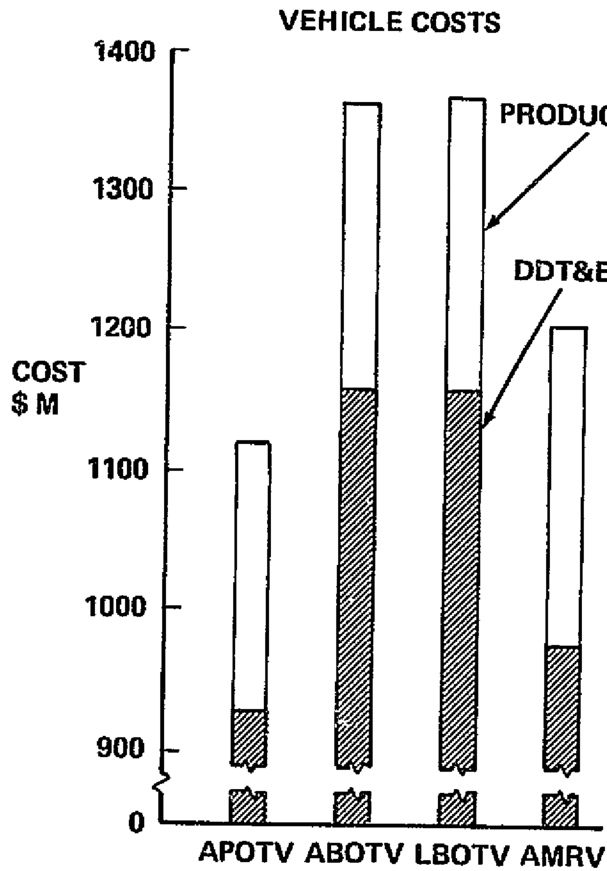
The data shown are given for mission ER1. Similar sensitivities would be demonstrated for the other DRMs. DDT&E deltas for ABOTV and LBOTV mainly reflect the added aeroballute and lifting brake systems. Production costs for all four modes vary by only $34M for two sets plus spares. Variation in CPM is mainly due to additional shuttle launches for the drop tanks, whose number varies with mission mode.

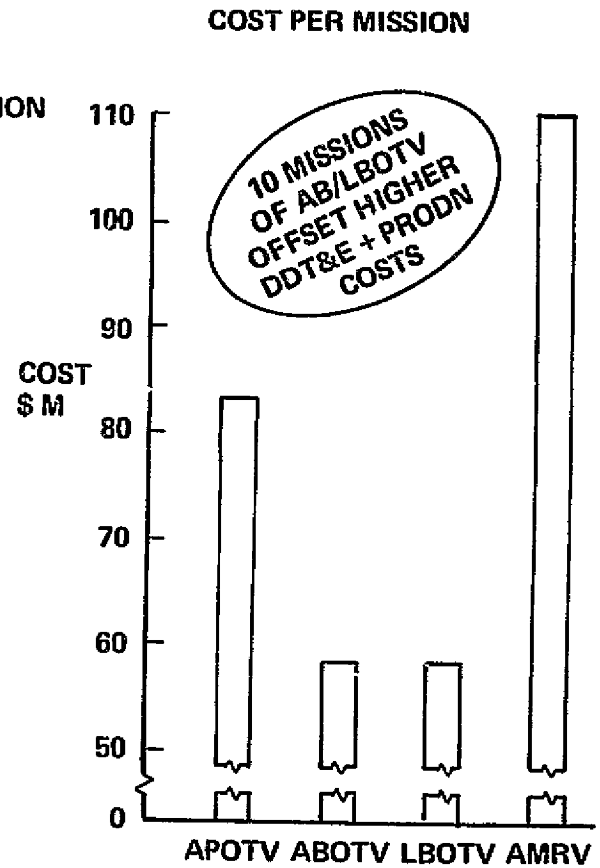
Compared to APOTV, the higher DDT&E and production costs for AB/LBOTV are recouped within 10 missions.

APOTV VS ABOTV VS LBOTV VS AMRV COSTS

GRUMMAN

- MISSION ER1
- 2 MAN FUNCTIONAL MINM. CAPSULE





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MISSION MODES - 'SINGLE POINT' FAILURE DISCRIMINATORS

In general, it is assumed that all systems and subsystems will have redundancy built into them to avoid single point failures. There are, however, some areas where it is impractical to avoid potential single point failures. These occur mainly in the provisions for deceleration.

APOTV has redundancy in the form of two main engines and redundant RCS thrusters for its all-propulsive deceleration.

ABOTV uses a ballute system which, if it fails, has no back-up. Similarly, the lifting brake of LBOTV has no back-up.

AMRV relies on several systems to successfully get the crew through entry to landing. These are listed on the illustration: each is potentially a 'single point' failure.

Additionally, there is the question of whether or not a single main engine is acceptable for manned flights. Grumman has baselined two engines for APOTV and AMRV whereas the OTV study contractors, who proposed ABOTV and LBOTV, have baselined one engine for all flights, including manned. While the number of engines could be edicted by NASA to be one or two for all cases, two engines may impact the use of exhaust gases to provide an aerodynamic spike at re-entry. We have, therefore, included the number of engines as a discriminator. Their inclusion or exclusion does not affect the result.

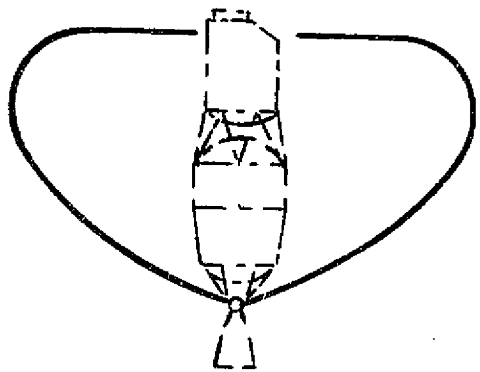
MISSION MODES: 'SINGLE POINT' FAILURE DISCRIMINATORS

GRUMMAN

APOTV

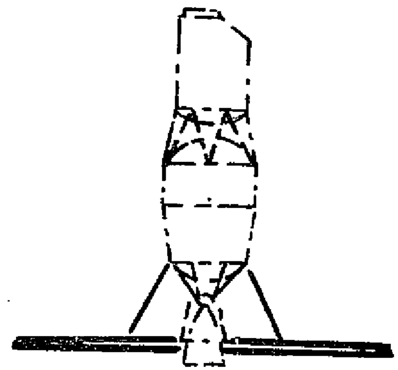
- NONE

ABOTV



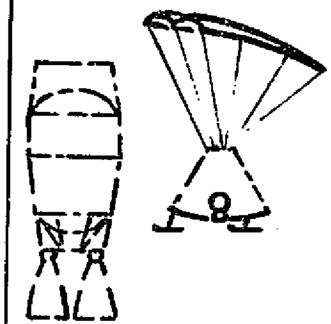
- BALLUTE
- ENGINE

LBOTV



- LIFTING BRAKE
- ENGINE

AMRV



- HEAT SHIELD
- DECEL. SRM
- PARAWING
- LANDING GEAR

RANKING:
(1) APOTV
(2) ABOTV/LBOTV
(3) AMRV

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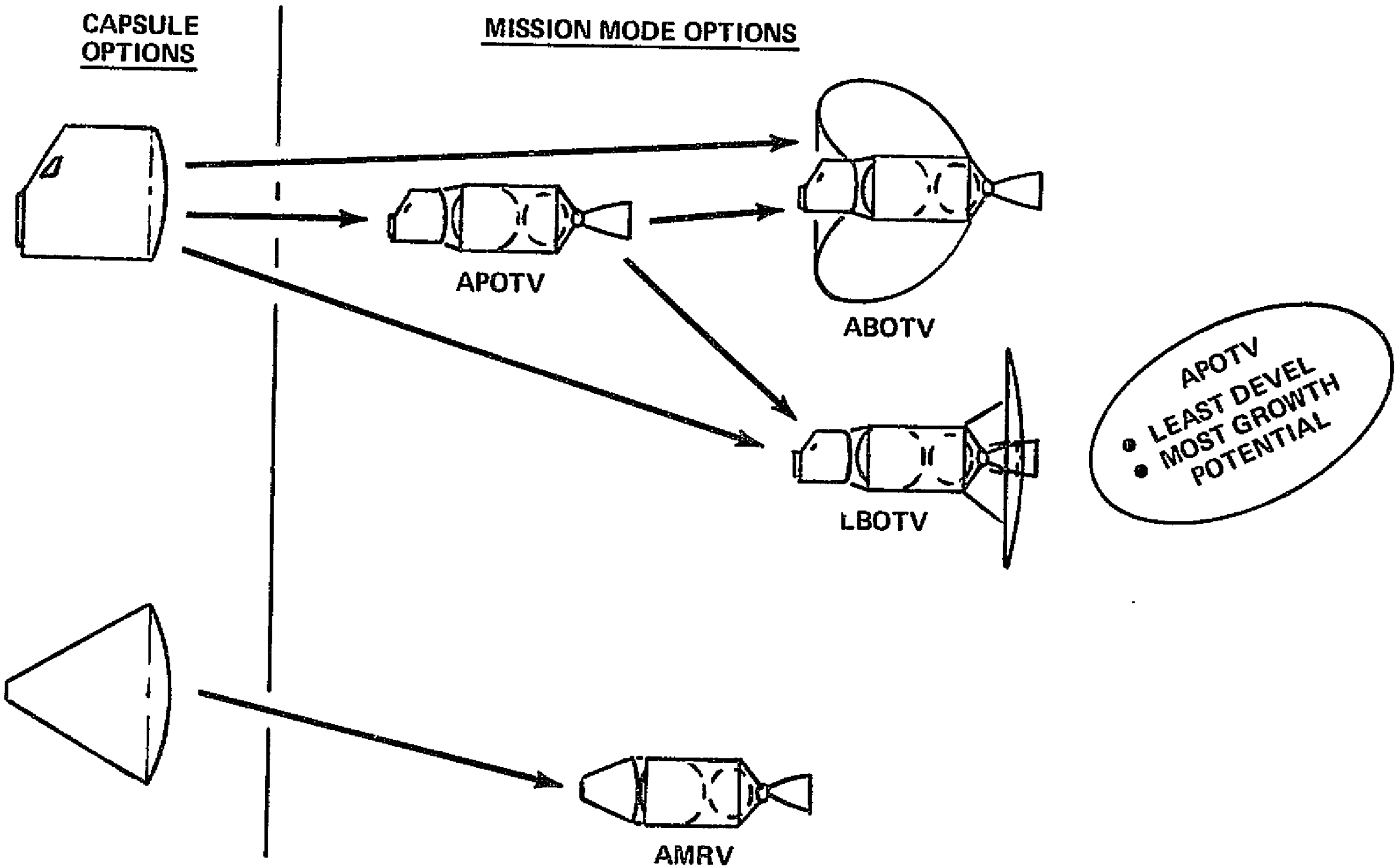
MISSION MODE EVOLUTION POSSIBILITIES

Evolution potential for the various mission modes is a factor in their evaluation. Firstly, the capsules, the 'non-entry' type, can be used on APOTV, ABOTV or LBOTV, while the 'direct entry' type is of use only on AMRV. Secondly, considering mission modes, APOTV can evolve to ABOTV or LBOTV by merely adding the ballute system or lifting brake system. Some upgrading of subsystems, such as GN&C, may be necessary.

Thirdly, AMRV, although it uses the same propulsion system as the others, requires the special 'direct entry' capsule which is dead ended since it cannot be readily increased in size, nor is it practical to use multiple capsules on one flight since their return, all at the same time, would be hazardous.

MISSION MODE EVOLUTION POSSIBILITIES

GRUMMAN



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DEVELOPMENT/TECHNOLOGY ISSUES FOR VARIOUS MISSION MODES

The facing page lists the unique requirements for development/technology issues that must be resolved for each of the mission mode configurations. These requirements, of course, are in addition to the development/technology issues relative to GEO suits, dexterous manipulator design, avionics hardware state-of-the-art, engine reliability, etc., that apply to all of the configurations.

The AOPTV's unique requirements, although not considered a major issue from a development risk and schedule viewpoint, do require ground simulation and flight test to demonstrate the capability to assemble crew capsule, propulsion core and Drop Tanks on-orbit and efficiently transfer propellant. The ABOTV and LBOTV configurations have similar development/technology issues, i.e., the development of an aerobraking system and the increased navigational accuracies for control of the skip-in, skip-out maneuver for aerobraking. The aerobraking system development is considered a major technology issue with significant development risk and schedule impact. The AMRV direct return is planned as a ground earth return mission mode. This requires the development of increased navigational accuracy and a landing system but neither item is considered to provide significant development risk or schedule impact.

MOTV

DEVELOPMENT & TECHNOLOGY ISSUES FOR VARIOUS MISSION MODES

GRUMMAN

MISSION MODE	DEVELOPMENT/TECHNOLOGY ISSUES - UNIQUE REQ'MTS
• APOTV	• ON-ORBIT ASSEMBLY OF CREW MODULE/PROP. MODULE AND DROP TANKS WITH FLUID TRANSFER FOR MAIN PROPELLANT, RCS, ETC.
• ABOTV	• DEVELOPMENT OF AEROBRAKING SYSTEM INCLUDING BALLUTE ATTACHMENT, ITS DEPLOYMENT AND JETTISONING WITH APPROPRIATE NAVIGATIONAL EQUIPMENT FOR THE SKIP-IN, SKIP-OUT MANEUVER
• LBOTV	• DEVELOPMENT OF AEROBRAKING SYSTEM INCLUDING LIFTING BRAKE, ITS REFURBISHMENT AND ITS ASSOCIATED NAVIGATIONAL HARDWARE FOR THE BRAKING MANEUVER
• AMRV (DIRECT RETURN)	• DEVELOPMENT OF INCREASED-ACCURACY NAVIGATION SYSTEM AND LANDING SYSTEM FOR LAND LANDING

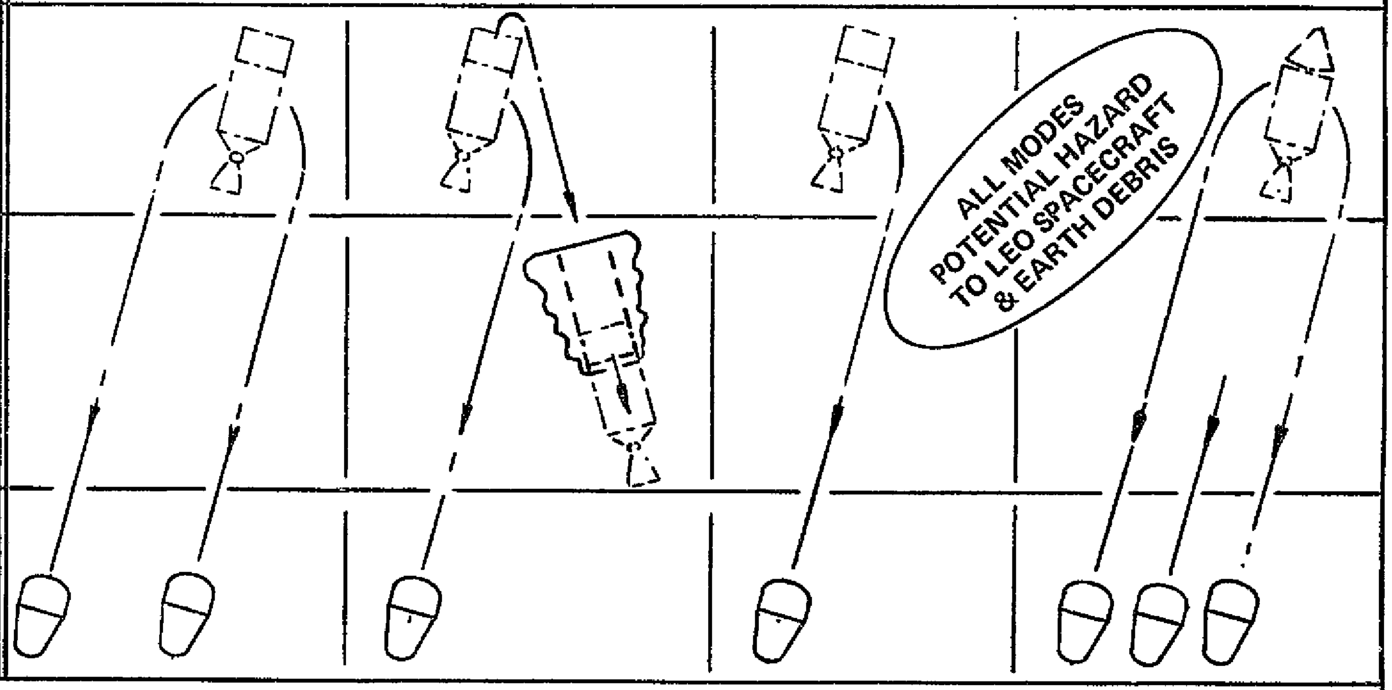
POTENTIAL DEBRIS HAZARDS - MISSION ER1 (TYPICAL)

Considering potential debris, drop tanks from 1-1/2 stage vehicles are jettisoned between LEO and GEO, then de-orbited to burn up in the atmosphere. They are a potential hazard to spacecraft orbiting between their jettison point and Earth; also, they are a potential hazard on Earth if they do not completely burn up. Taking ER1 as a typical mission, ABOTV and LBOTV each has one drop tank, APOTV has two, while AMRV has three tanks. With ABOTV, the jettisoned ballute is more likely to burn up than drop tanks, but it could be a hazard to LEO spacecraft. The ranking considers that drop tanks have more potential hazards than the ballute.

POTENTIAL DEBRIS HAZARDS – MISSION ER1 (TYPICAL)

- ALL JETTISONED ITEMS INTENDED TO DEORBIT & BURN UP

JETTISONED ITEM	APOTV	ABOTV	LBOTV	AMRV
BALLUTE				
DROP TANKS				
RANKING =	3	2	1	4



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MISSION MODES EVALUATION: APOTV VS ABOTV VS LBOTV VS AMRV

Preceding illustrations have given background for the mission modes evaluation, which now takes place. Discriminators are taken from the list of criteria given on an earlier illustration. Weighting factors are applied to some discriminators to emphasize the importance of those affecting safety and costs. The methodology for this comparison takes each mission mode concept and rates it with respect to the others for each discriminator. Each is given a ranking number (i.e., 1 for first, 2 for second, etc.) with the sum of rankings = 1 + 2 + 3 + 4 = 10 in each evaluation. To determine the score for each mode, the ranking points are subtracted from 5, then multiplied by the weighting factor.

Payload capability, costs, safety, evolution and debris are discussed on preceding charts.

Considering technology development, the materials criterion reflects development necessary for deceleration systems and, in the case of AMRV, the heatshield. Compared to APOTV, a more stringent GN&C subsystem is expected for ABOTV and LBOTV to control the flight path angle at entry and the AMRV has many elements in its entry and recovery system to be developed. The practicality of the aeromaneuvering flight return modes has still to be investigated seriously, and assessed.

Ground turnaround favors APOTV, a self-contained vehicle, followed by ABOTV which requires replacing the ballute; then LBOTV, where the lifting brake has to be inspected and serviced and, finally, the AMRV with its separated return capsule and all of its recovery system to be refurbished. Payload mounting, especially at return, has little problem for APOTV, but aerodynamic forces and c.g. problems present more difficulty for ABOTV and LBOTV. For AMRV, return cargo will be carried either inside the crew capsule or somewhere on the propulsion core for orbiter return.

APOTV is the winner of this evaluation by a clear margin and is the baseline mission mode.

MISSION MODES EVALUATION: APOTV VS ABOTV VS LBOTV VS AMRV

MOTV

GRUMMAN

DISCRIMINATORS	WTG FACTOR	APOTV		ABOTV		LBOTV		AMRV	
		RANK	SCORE	RANK	SCORE	RANK	SCORE	RANK	SCORE
• PAYLOAD CAPABILITY - DEPLOY & R.T.	1	3	2	1	4	2	3	4	1
• COSTS – DDT&E	2	1	8	3.5	3	3.5	3	2	6
– PRODN (2 SETS + SPARES)	1	1	4	2	3	3	2	4	1
– COST PER MISSION (ER1)	2	3	4	1.5	7	1.5	7	4	2
• SAFETY – SINGLE POINT FAILURES	2	1	8	2.5	5	2.5	5	4	2
• EVOLUTION – LEAST DEVEL START	1	1	4	3	2	3	2	3	2
– GROWTH POTENTIAL	1	1	4	3	2	2	3	4	1
• TECHN. DEVEL – MATERIALS	1	1	4	4	1	2	3	3	2
– SYS/SUBSYS	1	1	4	2.5	2.5	2.5	2.5	4	1
– RETURN FLT. MODE	1	1	4	4	1	3	2	2	3
• UTILITY – GRND. TURNAROUND	1	1	4	2	3	3	2	4	1
– P.L. MTG. IMPACT	1	1	4	3	2	2	3	4	1
• DEBRIS	1	3	2	2	3	1	4	4	1
			56		38.5		41.5		24

NOTE:

– SUM OF RANKINGS = 1+2+3+4=10 FOR EACH DISCRIMINATOR
– SCORE = (5 - RANK) x WTG. FACTOR

APOTV
- LEAST DDT&E/PRODN COST
- LEAST RISK
- EVOLVABLE

CREW CAPSULE/MISSION MODE CONCLUSIONS

This chart summarizes the conclusions drawn from evaluations of crew capsule options and mission mode options. Considering crew capsules, the two-man functional minimum is designed for competent performance of DRM tasks at an adequate level of crew comfort and to provide just sufficient stowage volume for necessary subsystems equipments. Capsule length can be increased to provide more internal volume at a penalty of 330 kg structure weight per meter of length. It has marginally lower costs than its rival, the 'basic' capsule.

The APOTV mission mode baseline has up to twice the payload capability of AMRV for the same number of STS launches, but less capability than ABOTV or LBOTV. It is considered to be a safer flight mode than the alternates, with simpler initial development and more growth potential. DDT&E and production costs are lowest for APOTV, but cost per mission is higher than for ABOTV or LBOTV.

MOTV

CREW CAPSULE/MISSION MODES CONCLUSIONS

GRUMMAN

- 2-MAN 'FUNCTINAL MINIMUM' CAPSULE BASELINED
  - PERFORMS ALL DRMs
  - ACHIEVES CELENTANO 'PERFORMANCE' LEVEL COMFORT FOR MISSIONS UP TO 16 DAYS
  - SUBSYSTEMS STOWAGE VOLUME ADEQUATE FOR ALL DRMs
  - MARGINALLY LOWER COSTS
    - SAVES $9M DDT&E + PRODN
    - SAVES $0.8M CPM
- APOTV MISSION MODE BASELINED
  - LEAST RISK DEVELOPMENT & OPERATIONS
  - MOST EVOLUTION POTENTIAL
  - PAYLOAD CAPABILITY
    - DEPLOY = 85%–95% OF ABOTV/LBOTV
    - ROUND TRIP = 50%–60% OF ABOTV/LBOTV
  - DDT&E + PRODN COSTS
    - $82M LOWER THAN AMRV
    - $240M LOWER THAN ABOTV/LBOTV
  - CPM COSTS
    - $1.5M LOWER THAN AMRV
    - $25M HIGHER THAN ABOTV/LBOTV

R80-1982-036P

MOTV RESPONSE TO VARIOUS EMERGENCIES

An emergency is any situation or event that places the crew and, ultimately, the mission, in jeopardy. There are three main categories of emergencies listed in the illustration: solar storm, crew illness/accident, and vehicle failure. Faced with any one of these emergencies, the crew may elect to work around the problem and continue the mission, or escape and end the mission. Much of this decision depends on whether the emergency is life threatening or not. Prompt and accurate diagnosis is imperative to assure crew safety and maximize mission success. Such a diagnostic capability is a requirement for the MOTV to eliminate unnecessary mission aborts. The details of such a system were spelled out in the mid-term review. The illustration identifies the specific response to various emergencies, and indicates the requirements for abort to assure crew safety.

MOTV RESPONSE TO VARIOUS EMERGENCIES

EMERGENCY TYPE		RESPONSE
SOLAR STORM	MODERATE RADIATION OVERDOSE	CONTINUE MISSION
	LIFE THREATENING HEAVY OVERDOSE	ESCAPE TO < 3Re IN 6 HR
ILLNESS/ACCIDENT	• VERTIGO • LACERATION • FRACTURE	CONTINUE MISSION
	LIFE THREATENING, i.e., • CORONARY • STROKE • SEVERE BURN	RETURN TO STS OR GROUND ASAP. STRESS ON CREWMEN DUE TO RE-ENTRY MUST BE ASSESSED
VEHICLE FAILURE	1ST FAILURE, NOT LIFE THREATENING	CONTINUE MISSION
	LIFE THREATENING, i.e., FAILURE LIFE SUPPORT SYST.	RETURN TO STS OR GROUND ASAP.

R80-1982-060P

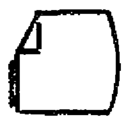
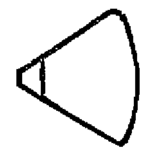
'EMERGENCY RETURN' OPTIONS

The impact of emergency return from GEO, on the baseline two-man functional minimum crew capsule and the APOTV mission mode, is treated as a side issue. If the AMRV had emerged as the baseline mission mode, then obviously emergency return would have had no impact at all.

The matrix shown here considers three possible crew capsule concepts for this return. A capsule which is not capable of direct entry, such as the baseline capsule, would fly as an APOTV for both normal flight and emergency return. Adding a lifeboat to this capsule provides a way for crew return directly to Earth in the event of emergency, with the capsule and propulsion collected in the LEO by shuttle, the normal flight mode. Of course, the crew could return directly to Earth from every mission by using the lifeboat, but that is not cost-effective.

Since APOTV is the baseline mission mode, we must consider the impact of a 'direct entry' capsule flying both normally and emergency in the AMRV mission mode. For normal flight, it could fly as an APOTV, but that mode is unlikely and is not considered here.

'EMERGENCY RETURN' OPTIONS

MISSION MODE	'NON-ENTRY' CAPSULE 	'NON-ENTRY' CAPSULE + ENTRY LIFEBOAT 	'DIRECT ENTRY' CAPSULE 
• NORMAL FLIGHT			
– APOTV			
– AMRV			
• EMERGENCY RTN.			
– APOTV		CAPSULE	
– AMRV		LIFEBOAT	

'EMERGENCY RETURN' MODE OPTIONS

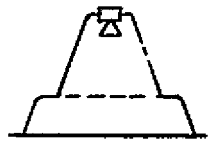
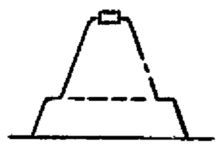
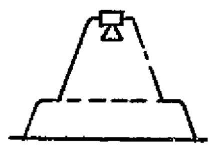
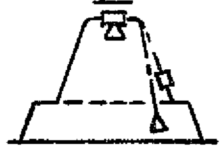
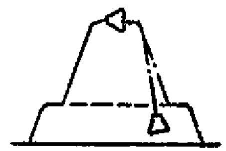
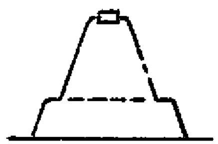
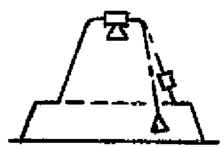
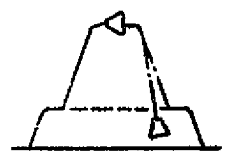
There are three classes of emergencies which necessitate immediate return from GEO. First is a severe solar storm for which it is necessary to descend to below an altitude equal to three earth radii. In this case, the MOTV would return to earth in its normal flight mode, either to rendezvous with a loitering shuttle or, in the case of AMRV, the crew returns directly to earth.

The current assumption is that subsystems will be designed to be fail operational/fail safe. If there is a malfunction, then the MOTV will abort the mission and return as it would for normal flight. With 'APOTV plus Lifeboat' mode, the crew has the option of returning directly in the lifeboat.

In the case of an ailing crewman, the objective would be to get the crewman to Earth as soon as possible. With APOTV mode, the returning capsule has to return via the loitering shuttle but with a lifeboat included on the APOTV, or with AMRV mode, the crew returns directly to KSC.

A following illustration gives GEO to Earth times for these options.

'EMERGENCY RETURN' MODE OPTIONS

EMERGENCY	APOTV	APOTV + LIFEBOAT	AMRV
SEVERE SOLAR STORM			
	DESCEND TO BELOW 3 EARTH RADII		
AILING SUBSYSTEM (FAIL OP/FAIL SAFE)		 OR 	
AILING CREWMAN			

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APOTV RETURN TIMES - GEO TO CAPE KENNEDY

Another concern, when evaluating emergency return modes, is the time required for the APOTV to return to Earth from GEO. Assuming that the emergency occurs towards the end of the mission, when no spare ΔV is available, this table gives a breakdown of minimum and maximum estimated times to perform necessary events.

It is assumed that the normal mission mode has an orbiter loitering in LEO for MOTV return to Earth.

APOTV RETURN TIMES – GEO TO CAPE KENNEDY (ASSUMING NO SPARE ΔV)

GRUMMAN

EVENT	MIN. TIME (HR)	MAX. TIME (HR)
GEO PHASE TO LINE OF NODES	0	12.0
GEO TO LEO	5.3	5.3
LEO PHASING	0	4.6
LEO RENDEZVOUS & SAFE	0.7	0.7
DEORBIT PREP	5.0	5.0
DEORBIT TO TOUCHDOWN	1.0	1.0
	12.0	28.6

NOTE – ASSUMES ORBITER LOITERING IN LEO

R80-1982-037P

'DIRECT ENTRY' CAPSULE RETURN TIMES - GEO TO CAPE KENNEDY

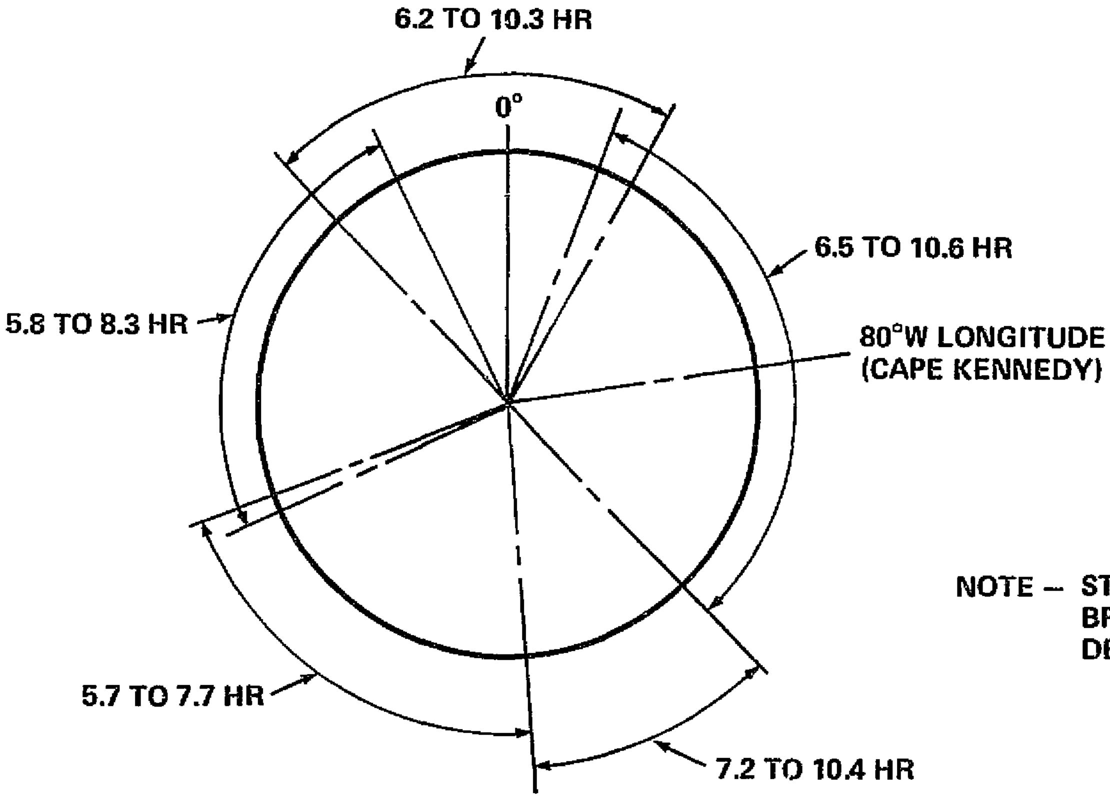
Times for the 'direct entry' capsule to return from GEO to Earth are given here for various bands of longitude which, together, cover the GEO orbit. This is a summary of a detailed study carried out earlier in this study extension and reported fully in our midterm briefing.

To return directly to Cape Kennedy from GEO takes, at the most, 10.6 hours.

MOTV

'DIRECT ENTRY' CAPSULE RETURN TIMES – GEO TO CAPE KENNEDY

GRUMMAN



10.6 HR MAX. RETURN TIME

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NOTE – STUDY EXTENSION 'MIDTERM BRIEFING' PROVIDES DETAILED INFORMATION

R80-1982-034P

CAPABILITY OF VARIOUS MOTV CONCEPTS TO HANDLE LIFE THREATENING EMERGENCIES

For each of the three categories of emergencies described on the previous illustration, requirements for abort are given together with the capabilities of various MTOV concepts to meet these requirements. The APOTV and AB/LBOTV concepts have equal capability as do the APOTV/Lifeboat and AMRV concepts. All concepts can adequately handle any emergency; however, the direct return concepts (APOTV/Lifeboat, AMRV) can return to the ground twice as fast. However, very few emergencies have the need for such a fast return; therefore, the significance of this additional performance capability is obscure at this time.

CAPABILITY OF VARIOUS MOTV CONCEPTS TO HANDLE LIFE THREATENING EMERGENCIES

GRUMMAN

TYPE OF EMERGENCY	REQUIREMENT	TIME TO RETURN-WORST CASE			
		APOTV	APOTV/ LIFEBOAT	AMRV	AB/LBOTV
SEVERE SOLAR STORM	3-5 HR WARNING ABORT TO <3 Re WITHIN 6 HR	<3 Re IN 6 HR*	<3 Re IN 6 HR	<3 Re IN 6 HR	<3 Re IN 6 HR*
SEVERE CREW ILLNESS/ACCIDENT	RETURN TO STS OR EARTH ASAP	22.6 HR TO STS	10.6 HR TO EARTH	10.6 HR TO EARTH	22.6 HR
VEHICLE FAILURE	RETURN TO STS OR EARTH ASAP	22.6 HR TO STS	10.6 HR TO EARTH	10.6 HR TO EARTH	22.6 HR

*REQUIRES BACKUP STS LAUNCH

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COSTS FOR PROVIDING EMERGENCY RETURN CAPABILITY

The data presented here is for DRM ER1. Sensitivities for the other DRMs will be similar. DDT&E deltas reflect, mainly, the costs for developing two capsules in the case of 'APOTV + Lifeboat' and the costs for entry and recovery systems in the case of AMRV. Production costs deltas follow the same reasoning. Cost per mission variation is mainly due to additional shuttle launches for the drop tanks, whose number varies with mission mode.

To provide a lifeboat on each APOTV mission, for return of the crew in the event of emergency, costs an additional total of $274M for DDT&E and production of two sets plus spares. Each flight has an additional cost of $26M.

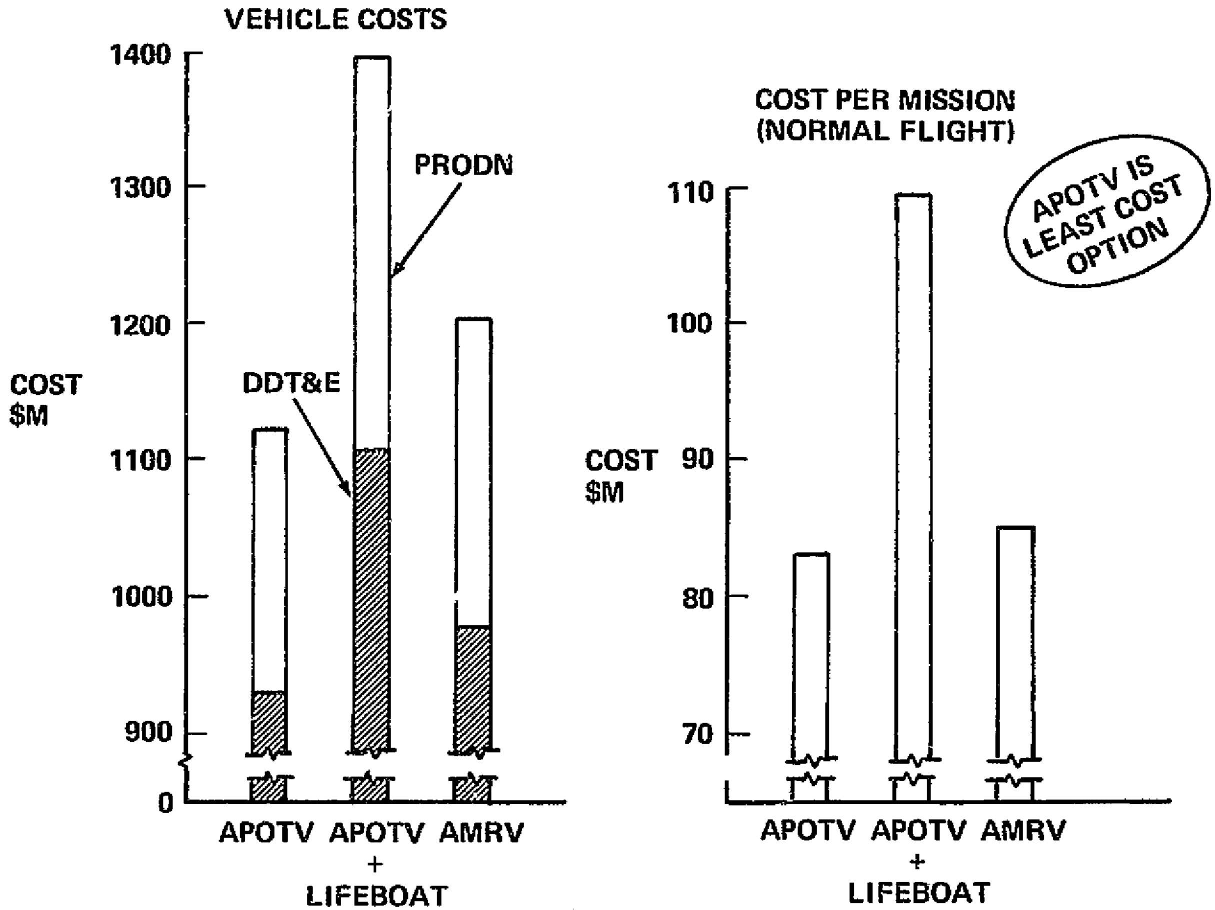
The alternative methods of providing for direct emergency return is to change the baseline mission mode from APOTV to AMRV. This entails cost penalties of $82M for DDT&E plus production (2 sets + spares) and $1.5M per mission. There are, of course, other drawbacks to the AMRV mode, as compared to APOTV, and these were discussed in the mission modes evaluation illustrations.

COSTS FOR PROVIDING EMERGENCY RETURN CAPABILITY – APOTV VS APOTV/LIFEBOAT VS AMRV

MOTV

GRUMMAN

- MISSION ER1
- 2-MAN FUNCTIONAL MINM CAPSULE



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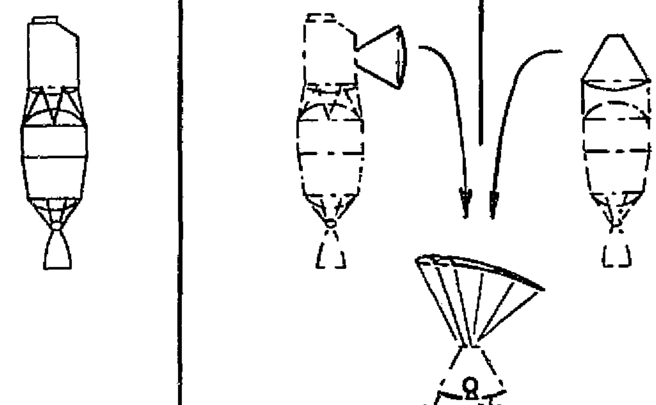
EMERGENCY RETURN: CONCEPTS & HAZARDS COMPARISON

As defined earlier in the 'logic flow' illustration, three criteria are considered in this impact analysis. The first concerns safety. This illustration shows concept sketches for the three candidate emergency return modes identified on the preceding illustration and discusses hazards associated with each. Considering 'single point' failures and using the discussion shown on a preceding illustration for a similar analysis, APOTV is preferred to the other modes. A sick crewman is subjected to around 4g landing loads in the orbiter but, typically, 6g at entry of a direct return capsule and possible higher g at its landing. Thus, APOTV has fewest potential hazards.

EMERGENCY RETURN: CONCEPTS & HAZARDS COMPARISON

GRUMMAN

APOTV HAS FEWEST POTENTIAL HAZARDS



	APOTV	APOTV + LIFEBOAT	AMRV
'SINGLE POINT' POTENTIAL FAILURES	• NONE	• HEATSHIELD • DECEL. SRM • PARAWING • LANDING GEAR	
DECELERATION/ LANDING 'g' (SICK CREWMAN)	4g (ORBITER)	6g (TYPICAL ENTRY)	

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OTV/MOTV NOMINAL MISSION CONTROL SUPPORT REQUIREMENTS

The accompanying illustration lists the nominal support required for the control of missions. The flight phases covered are preceded by extensive mission planning that starts early in the program and continues until mission rules and flight plans have been delineated and documented. The actual flight support would be the responsibility of the designated Mission Control Center (MCC), but SOC would provide the activation phase support and could be delegated to provide some of the in-flight and post-flight support.

OTV/MOTV NOMINAL MISSION CONTROL SUPPORT REQUIREMENTS

GRUMMAN

- ACTIVATION PHASE
  - POWER
  - COOLING
  - HARDLINE COMM/DATA RECORDING
  - GENERAL - COMPUTER LOAD VERIF, STATE VECTOR, IMU ALIGNMENT
- IN FLIGHT - DOCK, ORBIT MANEUVERS, RENDEZVOUS, DOCKING
  - DATA STOWAGE
  - COMM COORDINATION - MOTV - MCC/SOC
  - MONITOR
- POST FLT ON-STATION PHASE
  - DATA STOWAGE
  - COMM COORDINATION - MOTV - MCC/POCC

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OTV/MOTV CONTINGENCY MISSION CONTROL SUPPORT REQUIREMENTS

The accompanying illustration lists the additional support required during contingencies. The MCC would have the overall responsibility for providing the support during contingencies. It would use its resources and use SOC, the launch facility and the center responsible for the payload resources for support during any contingency.

OTV/MOTV CONTINGENCY MISSION CONTROL SUPPORT REQUIREMENTS

GRUMMAN

- ACTIVATION PHASE
  - DIAGNOSTIC
  - EMERGENCY RESCUE
- IN FLIGHT PHASE
  - OTV/MOTV SUBSYSTEMS SUPPORT - DIAGNOSTIC/CONTINGENCY WORKAROUND PROCEDURES
  - TARGETING
- POST FLT ON-STATION PHASE
  - OTV/MOTV SUBSYSTEMS SUPPORT - DIAGNOSTIC/CONTINGENCY WORKAROUND PROCEDURES
  - EVA EQUIPMENT SUPPORT
  - PAYLOADS ACTIVITY SUPPORT

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'EMERGENCY RETURN' IMPACT CONCLUSIONS

APOTV was selected as the baseline mission mode after evaluating mode options for performing a normal mission, with no consideration of immediate return due to emergency. Staying with the APOTV, it can return to earth from GEO in 12 hours minimum, 28.6 hours maximum. If this time delay is acceptable, then it is the least hazardous and most comfortable way of returning, as well as being lowest in cost.

The alternate is for the crew to descend in a 'direct entry' capsule. The time from GEO to ground is reduced to 5.7 hours minimum, 10.6 hours maximum, but it is a riskier mode and deceleration g's are higher. Cost penalties for two alternate methods of direct return are given in the illustration.

MOTV

'EMERGENCY RETURN' IMPACT CONCLUSIONS

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APOTV COMPARED TO 'DIRECT ENTRY' CAPSULE:

- TAKES BETWEEN 7 HR AND 18 HR LONGER FROM GEO TO GROUND
- LEAST HAZARDOUS
- MORE COMFORTABLE
- PRODN + DDT&E COSTS : $82M LOWER THAN AMRV
  : $270M LOWER THAN APOTV & LIFEBOAT
- CPM COSTS : $1.5M LOWER THAN AMRV
  : $26M LOWER THAN APOTV & LIFEBOAT

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MOTV

GRUMMAN

INTRODUCTION

OPERATIONAL REQMTS
ANAL. & DEFINITION

MOTV CONCEPTS SUMMARY
EVALUATION

CONCLUSIONS &
RECOMMENDATIONS

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MOTV

TURNAROUND CONCLUSIONS

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RECOMMENDED TURNAROUND MIX

- SPACE BASING MOTV AT SOC WITH PERIODIC RETURN TO GROUND FOR LABOR INTENSIVE TASKS (MAJOR OVERHAUL) RESULTS IN MINIMUM RECURRING COSTS
  - REDUCES STS TRANSPORTATION COSTS BY APPROX $30M PER YEAR (TRAFFIC MODEL SENSITIVE)
  - DECOUPLES STS & MOTV TURNAROUND
- PRESSURIZED HANGAR AT SOC REDUCES LABOR COSTS BY APPROXIMATELY 50%

MOTV CONCEPTS SUMMARY EVALUATION

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- 2-MAN FUNCTIONAL MINIMUM CREW CAPSULE HAS HIGHEST POINT SCORE OF CAPSULE CONCEPTS CONSIDERED
  - CAN PERFORM ALL DRMs AND CAPTURES 15 OF 19 GENERIC MISSIONS
  - HAS ADEQUATE SUBSYSTEM STOWAGE VOLUME
  - CREW ACCOMMODATIONS MEET CELENTANO "PERFORMANCE" FOR MISSIONS UP TO 16 DAYS
  - COSTS ARE MARGINALLY LOWER THAN OTHER CONCEPTS
- APOTV MISSION MODE IS RECOMMENDED FOR EARLY MANNED MISSIONS
  - LEAST RISK
  - LOWEST DEVELOPMENT COSTS
  - GREATEST EVOLUTION POTENTIAL

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MOTV

MOTV WITH TANDEM STAGE – PROPULSION

GRUMMAN

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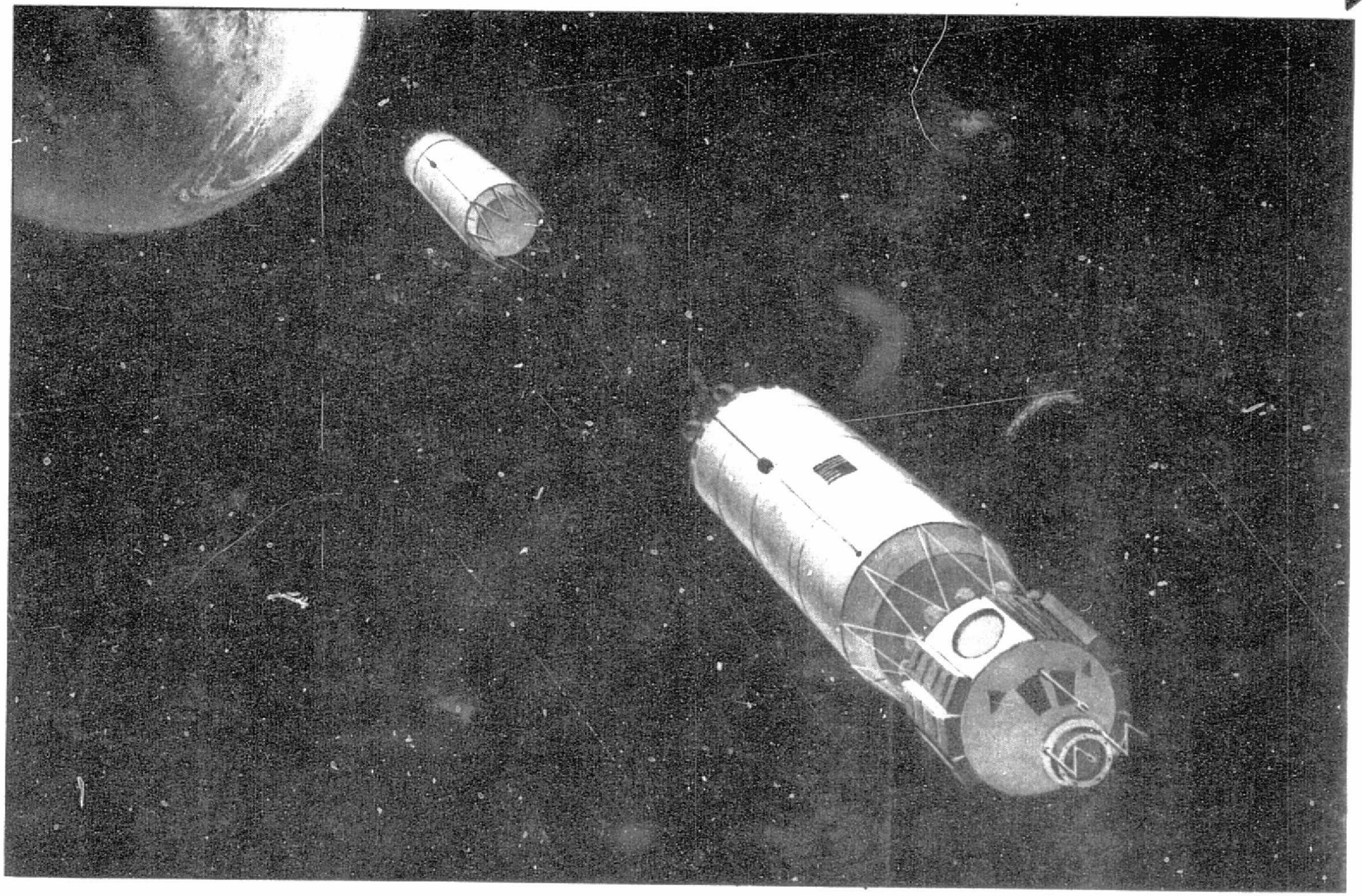

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